सत्यमेव जयते

INDIAN AGRICULTURAL
RESEARCH INSTITUTE, NEW DELHI

I.A.R I.6.
GIP NLK—H-3 I.A.R.I.—10 5-55—15,000

THE OHIO
JOURNAL OF SCIENCE

VOLUME XLI — 1941

LAURENCE H. SNYDER, Editor-in-Chief

PUBLISHED AT COLUMBUS, OHIO, BY THE

OHIO STATE UNIVERSITY
and the
OHIO ACADEMY OF SCIENCE

THE OHIO JOURNAL OF SCIENCE

ADMINISTRATIVE BOARD

For Ohio State University	For Ohio Academy of Science
F. C. Blake	F. E. Ray
E. N. Transeau	J. R. Patrick

EDITORIAL STAFF

Laurence H. Snyder	Editor in Chief
Glenn W. Blaydes	Associate Editor
Bernard S. Meyer	Business Manager
John A. Miller	Associate Business Manager

J. B. Park	Agronomy	J. Ernest Carman	Geology
R. A. Knouff	Anatomy	W. H. Shideler	Paleontology
H. H. M. Bowman	Botany	C. W. Jarvis	Physics
R. C. Burrell	Chemistry	F. A. Hitchcock	Physiology
E. Lucy Braun	Ecology	J. P. Porter	Psychology
F. C. Waite	Embryology	E. R. Hayhurst	Public Health
G. D. Hubbard	Geography	R. V. Bangham	Zoology

THE OHIO JOURNAL OF SCIENCE

Is published jointly by the Ohio State University and the Ohio Academy of Science.

TABLE OF CONTENTS

NUMBER 1—JANUARY

PAGE

Quantitative Plankton Studies of Turkeyfoot Lake, Near Akron, Ohio, *Walter C. Kraatz* 1

Sebekia oxycephala (Pentastomida) from Florida Fishes and Some Notes on the Morphology of the Larvae. . *Carl Ernest Venard and Ralph V. Bangham* 23

The Alimentary Tract of *Vespula maculifrons* Buy. (Hymenoptera: Vespidae)........ *Robert Thomas Mitchell* 29

Quantitative Determination of Rhythmicity in Organisms...... *Orlando Park* 39

Presence of the *Ligamentum botalli* in the Golden Eagle *Aquila chrysaëtos* (L.), the Red-tailed Hawk *Buteo borealis borealis* (Gmelin), and the Common Pigeon *Columba livia* (L.)........ *Fred H. Glenny* 46

Book Notices........ 22, 28, 45, 49, 50

NUMBER 2—MARCH

The Generic and Specific Status of Four Ohio Spiders of the Genus Agelenopsis........ *Paul J. Seyler* 51

The Sensitivity of Anemometer Cups...... *John G. Albright and G. E. Klein* 70

Butomus umbellatus in America........ *Earl L. Core* 79

A New Genus (Knullana) and Two New Species of Leafhoppers (Homoptera-Cicadellidae) from Mexico........ *Dwight M. DeLong* 86

Studies in Human Inheritance XX. Four Sets of Alleles Tested for Incomplete Sex Linkage........ *Laurence H. Snyder* 89

The Distribution of *Cambarus sloani* Bundy, in Ohio........ *Rendell Rhoades* 93

A Systematic Study of the Main Arteries in the Region of the Heart—Aves. II. (*Crotophaga ani*), (*Saurothera merlini*), and (*Coccyzus americanus*)........ *Fred H. Glenny* 99

Book Notices........ 101–102

NUMBER 3—MAY

Presidential Address—A Present Day Examination of the Postulates of John Dalton........ *Wm. Lloyd Evans* 105

Research on the Central Auditory Mechanisms: Some Recent Methods and Results........ *E. A. Culler* 117

Some Social Aspects of Deafness........ *E. R. Abernathy* 123

The Development of High Voltage for the Production of Neutrons and Artificial Radioactivity........ *E. U. Condon, Ph.D.* 131

A Comparative Study of Neutron- and X-Radiation upon Biological Tissues in the Cancer Problem........ *Isadore Lampe, M.D.* 135

Cancer: Clinical and Experimental Aspects....... *Francis Carter Wood, M.D.* 139

The Classification of Nerve Fibers........ *Herbert S. Gasser* 145

The Interaction of Neurones........ *R. W. Gerard* 160

Encephalization of Motor Functions During the Evolution of the Primate Nervous System........ *J. F. Fulton, M.D.* 173

A Scaled Model of a Proposed Protein Structure........ *Edward Mack, Jr.* 183

Ecological Factors and Drosophila Speciation........ *Warren P. Spencer* 190

The Origin of Ohio Soils........ *Guy W. Conrey* 201

TABLE OF CONTENTS—[*Continued*]

PAGE

Prehistoric Factors in the Development of the Vegetation of Ohio, *Edgar Nelson Transeau* 207

The Aerial Traverse. An Application of Aerial Photography to Geographic Studies............ *John L. Rich* 212

Postglacial Vegetation in the Erie-Ohio Area............ *Paul B. Sears* 225

The Differentiation of the Deciduous Forest of the Eastern United States, *E. Lucy Braun* 235

Recent Trends in Horticultural Research............ *J. H. Gourley* 242

Professor John Henry Schaffner............ *Adolph E. Waller* 253

Book Notices............ 134, 138, 144, 159, 172, 200, 206, 211, 241, 250

NUMBER 4—JULY

The Ohio Academy of Science (Mostly Historical)..... *William H. Alexander* 288

The Saga of Paddy's Run............ *Stephen R. Williams* 313

Additions to the Revised Catalogue of Ohio Vascular Plants. IX, *Clyde H. Jones* 328

Book Notices............ 327, 345, 346

NUMBER 5—SEPTEMBER

The Heart and the Red Blood Cells as Generator and Distributors of Static Electricity, *George Crile, M.D., Otto Glasser, Ph.D., and Daniel P. Quiring, Ph.D.* 347

Inexpensive Equipment for the Preparation and Concentration of Pure D_2O or of Deuterium-Rich Water. Description of Construction and Operation of the Former Ohio State University Heavy Water Plant, *Herrick L. Johnston and W. Heinlen Hall* 357

The Geography of the Bellevue Area............ *Ruth Rockwood Daugherty* 366

Black Widow Spider (*Latrodectus mactans* Fab.) Distribution in Ohio, *Frank Merrick Semans* 380

Nine New Coleoptera—(Plastoceridae, Buprestidae and Cerambycidae), *Josef N. Knull* 381

Hydrogen-ion Concentration and the Initiation of Growth.... *Cyril J. Corum* 389

Book Notices............ 356, 365, 379, 388

NUMBER 6—NOVEMBER

Annual Report of the Ohio Academy of Science, 1941............ 397

A Preliminary Survey of Mexican Psyllidae (Homoptera).... *John S. Caldwell* 418

Studies in Antibiosis Between Bacteria and Fungi. II. Species of Actinomyces Inhibiting the Growth of *Colletotrichum gloeosporioides* Penz. in Culture............ *Const. J. Alexopoulos* 425

The Physiological Activity of Certain Alcohols and Ethers to Goldfish, *Harvey C. Brill and Alexander K. Presnell* 431

Parasites from Fish of Buckeye Lake, Ohio............ *Ralph V. Bangham* 441

Relation of Sauger Catch to Turbidity in Lake Erie........ *Kenneth H. Doan* 449

Supplementary Note on the Effect of the 1938 Hurricane..... *Mary D. Rogick* 453

Protozoan Parasites of the Orthoptera, with Special Reference to Those of Ohio. III. Protozoan Parasites in Relation to the Host and to Host Ecology............ *Frank Merrick Semans* 457

Book Notices............ 424, 440, 464

Index to Volume............ 465

THE OHIO JOURNAL OF SCIENCE

VOL. XLI JANUARY, 1941 No. 1

QUANTITATIVE PLANKTON STUDIES OF TURKEYFOOT LAKE, NEAR AKRON, OHIO

WALTER C. KRAATZ,
Department of Biology, University of Akron,
Akron, Ohio

INTRODUCTION

Turkeyfoot Lake is the southernmost of a chain of lakes and reservoirs known as the Portage Lakes, partly within but mostly south of the city of Akron. The three lakes farthest south, with connecting channels, all on one level higher than the other lakes, are shown on the accompanying map (Figure 1).

An entirely new reservoir, Nimisila, is in the process of filling up. It will have its outlet into the southern end of Turkeyfoot.

Turkeyfoot has an arm northwest called Rex Lake and a more broadly connected eastern lobe, Mud Lake, and the rest of it is partly divided into lobes. In the large, central southern lobe, collections were made in a central area having a depth of 13 to 14½ meters, maybe more at some places. The collecting station is marked "X." Besides plankton collections, bottom samples were made with Ekman dredge, but bottom organisms are not reported in this paper. One central station has been found adequate in some recent work (Ricker, 1938) for pelagic limnoplankton.

Near the entrance of Mud Lake into Turkeyfoot, marked "Y" on the map, collections were also made at two stations, both shallow, differing somewhat in nature of bottom, but these are not reported in this paper.

The aims were to show seasonal and vertical distribution of the chief plankton organisms. Temperature records and chemical tests of dissolved O_2, dissolved CO_2 and pH were made. No extensive limnological or ecological studies were possible in the limited time available.

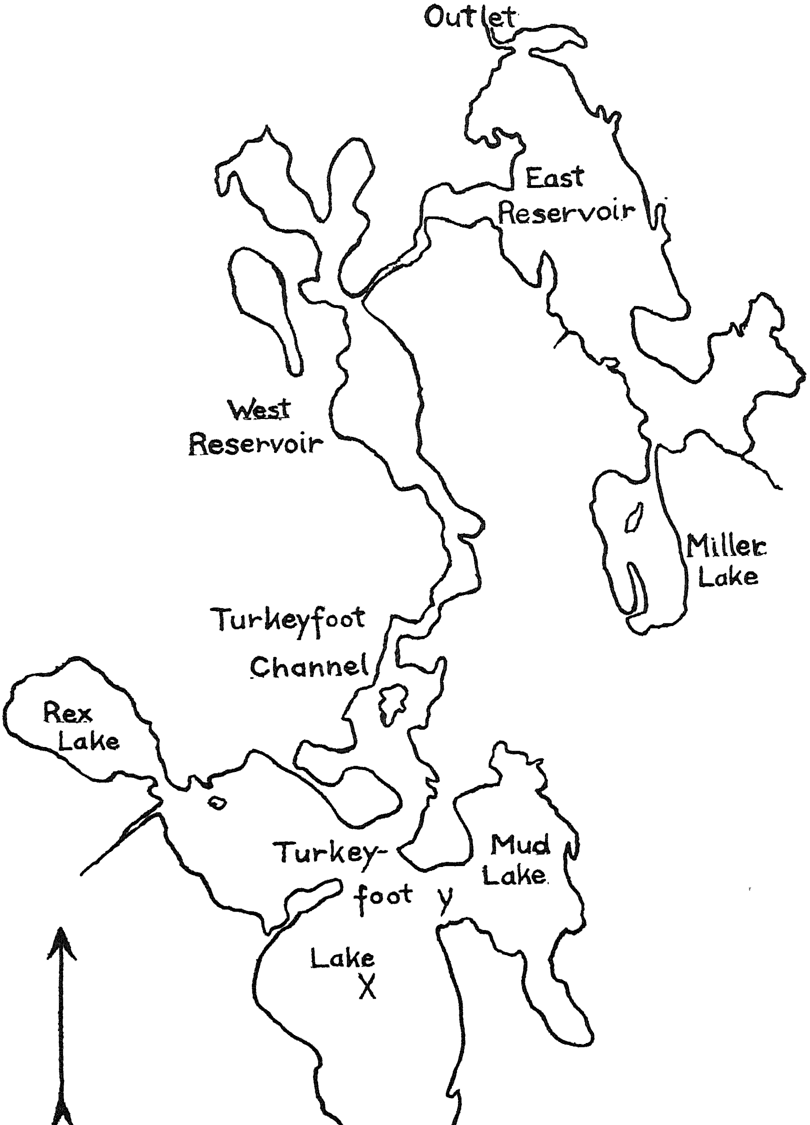


Fig. 1. Map of East Reservoir, West Reservoir and Turkeyfoot Lakes, and smaller Ponds and Lakes. Roads, bridges, etc., are omitted. Copied from a map of the Ohio Division of Conservation.

Very little has been published on these lakes, though much uncorrelated collecting has been done. One paper on net-plankton of East and West Reservoirs appeared (Kraatz, 1931). Recently a paper (Kraatz, 1940) which is part of this same study, appeared, serving as an introduction to the present paper.

ACKNOWLEDGMENTS

The Division of Conservation of Ohio donated a Foerst plankton trap, Kemmerer-Foerst water bottle and also an Ekman dredge; without this equipment the work would have been impossible. Particular thanks are due to Mr. E. L. Wickliff for securing this equipment and encouraging the work. At the beginning of this work Mr. Lee S. Roach demonstrated the collecting and laboratory methods as done in the state conservation work. Chemical tests were performed by Miss Eleanor Mueller and later by Mr. Samuel Caplin. On each collecting trip some student assistant or other student helped with the apparatus and collection. Mr. Walter K. Harris, Portage Lakes Conservation Officer, gave generously of his time, running the state motor boat on all trips, without which the collection would have been impossible.

Dr. L. H. Tiffany, and after his leaving Ohio, Dr. C. E. Taft, identified some algae and Dr. L. E. Noland, some Protozoa. The extent of their examination of various types of organisms is hardly realized in this paper, where only the main plankters appear. Mr. Bill J. Barkley copied the graphs in presentable form.

Microscopes, counting cells, and all chemical and other materials, and also the deep sea thermometer and Foerst centrifuge belong to the Biology Department, University of Akron.

PLANKTON COLLECTING AND LABORATORY METHODS

Collections were made monthly at a convenient time, usually on a Saturday, from about the 15th to the 20th of the month, starting in August, 1936. None were secured in December, 1936, or February, 1937; thin ice proved unsafe for walking to the collecting station, but too thick for the boat to get through. A small collection was made from the boat January, 1937. Collections continued from March through October, 1937. November, 1937, was unavoidably missed. On December 4 a small collection was made through rather thin ice, but only at the shallow Mud Lake station. In January, 1938, a collection unfortunately incomplete, was made through thick ice; in February, an incomplete one from boat; but complete collections from

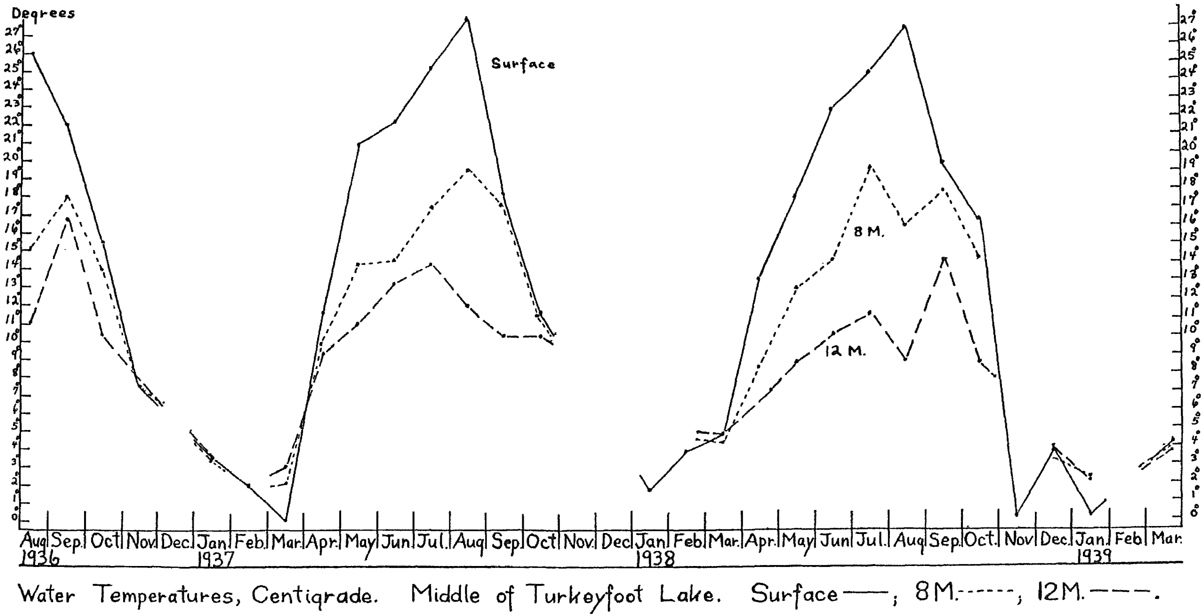


Fig. 2. Water Temperatures of Turkeyfoot Lake.

March onward. Circumstances again prevented a November collection, but an early December collection was made from a boat. A collection through ice was made January, 1939; none was possible due to weather conditions in February, but a final collection was made in March.

Methods of collecting have been adequately given in the paper referred to above (Kraatz, 1940) and likewise laboratory methods explained. The main aim of the paper was to compare the number of organisms per liter of lake water as secured by the trap concentrated by its net, with those secured by the water bottle, concentrated by the centrifuge. It was shown that for organisms falling within the general scope of netplankton, generally the trap was better, largely because, having a much larger initial sample and more concentrated laboratory vial sample and counting cell sample, much larger numbers of organisms were actually counted and less multiplying required to get organisms per liter, than in the case of the water bottle samples. It was shown that certain kinds of blue-green algae of low specific gravity were lost in centrifuging. But it was also seen that most kinds of diatoms were collected often in significantly larger numbers with the water bottle. The organisms per liter of net and centrifuge plankton in neighboring columns for all collections were studied and discrepancies compared as to their significance. Usually it was possible to determine for kinds or groups of organisms which technique was best. The selection is shown in the table and discussion later in this paper.

TEMPERATURE RECORD

A deep-sea reversing thermometer (H. B. Instrument Co.) was used from March, 1937, on. Previously an ordinary chemical thermometer was used by hurriedly placing it immediately after collection into the jar holding water from the brass water bottle as collected from just under surface, at 4 m., 8 m., and 12 m. These were the water samples later used for centrifuging. From August, 1936, to June, 1937, inclusive, records are available only for these four levels, but from July, 1937, to March, 1939, records were made at meter intervals. In certain winter months no records were secured from the middle of the lake.

The accompanying table shows the Turkeyfoot station "X" record, in centigrade for period in which meter interval readings were taken. The graph shows for the entire collecting period, the surface record, 8 m., and 12 m. records; the 4 m. curve very close to and slightly below the surface curve was not included because it would add to the confusion of lines. (See Table I and Fig. 2.)

It should be noted that the only temperature readings below ice from the middle of Turkeyfoot were January, 1938, (unfortunately only a surface reading) and January, 1939. Record marked * was close to shore at south end of lake; it was impossible to get out to the middle of the lake. One temperature record of surface water, March, 1937, was slightly below 0° C. The surface was not ice-covered; it was very windy and air temperatures below freezing. One temperature reading below ice in Mud Lake (station D) December, 1937, was 2.3° C.

TABLE I

WATER TEMPERATURE, DEGREES CENTIGRADE, MIDDLE TURKEYFOOT LAKE

	July 19, 1937	Aug. 20, 1937	Sept. 18, 1937	Oct. 16, 1937	Nov. 20, 1937	Dec. 4, 1937	Jan. 15, 1938	Feb. 19, 1938	Mar. 19, 1938	April 16, 1938	May 21, 1938	June 18, 1938	July 16, 1938	Aug. 20, 1938	Sept. 17, 1938	Oct. 15, 1938	Nov. 26, 1938	Dec. 3, 1938	Jan. 28, 1939	Feb. 25, 1939	Mar. 25, 1939
Surface	25.0	27.6	17.7	11.6			1.8	3.8	4.7	13.2	17.7	22.4	24.5	27.1	19.6	16.5	0.4	3.6	0.2		4.6
1 m	24.8	27.2	16.9	11.8					4.7	11.8	17.7	22.4	24.4	26.5	20.2	15.8	Off shore at Kelper's landing	3.6	1.8		4.4
2 m	24.5	27.1	17.4	11.6					4.4	11.6	17.7	22.4	24.4	26.4	20.2	15.6		3.6	2.0		4.4
3 m	24.4	26.8	17.5	11.6					4.4	10.9	17.6	22.2	24.3	26.2	21.0	15.6		3.6	2.2		4.4
4 m	24.0	25.2	17.4	11.5					4.8	10.4	16.6	22.0	24.3	26.0	20.6	15.5		3.4	2.2		4.3
5 m	22.1	22.7	17.0	11.5					4.8	10.2	15.6	20.2	24.4	24.0	20.6	15.4		3.4	2.2		4.4
6 m	20.6	21.5	17.4	11.5					4.4	9.7	15.6	20.1	23.0	22.5	20.6	15.0		3.4	2.2		4.0
7 m	19.2	19.2	17.4	11.4					4.4	9.1	14.5	17.0	21.1	18.8	20.2	14.6		3.3	2.3		4.0
8 m	17.3	19.4	17.4	11.4					4.4	8.5	12.9	14.4	19.4	16.2	18.0	14.4		3.3	2.3		4.0
9 m	17.0	14.8	14.7	11.2					4.3	8.0	12.1	9.6	16.3	15.5	16.0	13.8		3.3	2.4		4.0
10 m	14.6	12.3	12.4	11.2					4.2	8.0	9.8	9.9	10.4	12.9	15.4	11.6		3.4	2.4		4.0
11 m	14.4	11.6	10.3	10.8					4.6	7.4	8.7	8.2	9.4	9.8	14.8	10.4		3.4	2.6		3.9
12 m	14.1	11.8	10.2	10.2					4.6	7.1	8.6	10.2	11.4	8.8	14.4	8.6		3.8	2.2		3.9
13 m	12.0	11.8	*	9.1					4.6	6.4	7.9	8.3	12.1	8.0	9.8	8.8		3.8	2.5		3.8
14 m	11.8	10.4	*	*					*	*	7.5	7.8	11.4	8.8	*	8.7		3.8	*		3.8
15 m	11.0	10.2	*	*					*	*	*	*	*	*	*	*		*	*		*

Close similarity in seasonal temperature changes is shown in the two and one-half years of temperature curves. A series of spring and fall readings practically uniform from top to bottom indicates clear cut spring and fall overturns. No real thermocline can be noticed, however.

CHEMICAL TESTS

For chemical tests, made for each of the four levels surface, 4 m., 8 m., and 12 m., water was discharged from the brass water bottle into 250 cc. glass bottles which were tightly glass stoppered after being filled to overflowing. From each collection two such bottles were taken, the rest allowing for the liter centrifuge sample previously noted. A moist cloth over the bottles tended to keep down their temperature somewhat in transporting them back 9 miles to the laboratory, where tests were made. For the 32 month total period, 26 complete and two incomplete sets of samples for tests were available.

The outboard motor patrol boat used for most trips was so crowded that chemical tests on board were impossible. A much larger boat was available September and October, 1936, and from April to October, 1937, when it was removed from the lake. It could not be used in intervening months because the water level was too low in parts of the channels. But there was no thought of doing part of the chemical testing on board, until comparison of a year's oxygen records disclosed what seemed some rather unreasonably high quantities of dissolved oxygen. In September and October, 1937 trips, it was arranged to do the initial steps of the oxygen test on the big boat. These, after completion in laboratory, did show for reasons unknown somewhat lower oxygen content than the tests on water collected at same time, run entirely in the laboratory. The technique was precisely the same, and by the same person in this period of work; the method was the Rideal Stewart modification of the Winkler method. (Standard Methods of Water Analysis, 5th Ed., 1923.)

Because of a possible invalidity of the end results of some oxygen tests, it is not considered worth while to present a table of all results. Nevertheless, a summary is given, all figures being p.p.m. Surface water oxygen content varied from 6.13 (August, 1937) to 14.59 (January, 1938), but was usually between 10 and 14; of 28 surface monthly readings, the only ones below 10 were November, 1936, August, 1937, August, September and October, 1938, but also more oddly, March, 1939. For the most part oxygen content was high in spring. Several instances occurred of slightly higher oxygen content at 8 and 12 m. than at surface. Other surprises were some erratic ups and downs from month to month. But in many late summer and fall months, there was a marked decrease from top to bottom, especially in August and October, 1936, and June, August, September and October, 1938. The lowest content of all, at 12 m. was 2.20 in September, 1938. But usually the oxygen content at 4 m., 8 m., and 12 m., was not materially lower than surface content, in the fall overturn, November, during the winter, and during spring overturn, to beginning of summer.

The dissolved CO_2 was determined by the standard method of phenolphthalein indicator and n/44 sodium hydroxide. No CO_2 was recorded for surface waters except under ice, January, 1938, when there were 0.4 p.p.m. and in February, 1938, 0.2 p.p.m. At 4 m. there were 7 instances of some CO_2, at 8 m. 19 instances and at 12 m. 19 instances, out of 26 cases of total vertical test results. There were actually 6 monthly readings, January, March, and April, 1937, March and April, 1938, March, 1939, when the CO_2 readings were zero from top to bottom.

The pH was determined by the La Motte colorimetric method. Throughout the work, pH varied from 7.6 to 8.8 in surface water, higher alkalinity occurring in late summer and early fall. There were several cases of identical pH through the entire vertical range, 8.0 in April, 1937, March, 1938, 7.8 in December, 1938, and 7.6 in February, 1938. More often there was a slightly lower reading (less alkalinity) in deeper water, but the largest vertical range at any one time was 1.6 (and only 9 cases of ranges of 1.0 or above). The lowest alkalinity was 7.1 at 12 m., October, 1936, and the total range was 1.7.

KINDS OF PLANKTON ORGANISMS

Plankton were identified to genera. Species determination for all was impossible. In many cases a genus was represented by only one species.

Since routine examination was in the Sedgwick-Rafter counting cell, requiring low power (16 mm. objective) many nanno-plankton, if small and scattered, may have been omitted. Six types of real nanno-plankton were studied. Three of these were smaller species of genera also included in net plankton.

Twenty-seven net plankton genera and separately six nanno-plankton were tabulated completely. For each month or collection, the separate number of organisms per liter from surface water, 4 m., 8 m., and 12 m. were recorded. In this paper these longer tables are omitted.

Most of the data on organisms per liter of the twenty-seven genera were those of the trap-net collections; some were from the water bottle centrifuged samples. The selection was made on the basis of studies reported on in the paper comparing critically the two collecting methods (Kraatz, 1940) and referred to in the introductory remarks on methods, above.

The blue-green alga Aphanizomenon counts were from centrifuged samples because in times of maxima far greater numbers were secured than from trap-net samples. The other Cyanophyceae were from trap-net counts, because centrifuging operations failed to retain the vast majority of the water bottle specimens.

On the other hand, diatom counts used were from water bottle samples for in these significantly larger numbers were found, especially in times of maxima, though not at all times. One exception was Stephanodiscus where net counts were used. This may seem arbitrary, but this genus was found in far more net samples than water bottle samples; numbers of water bottle samples had none while the comparable net sample had appreciable numbers. Possibly this is explained by the combination of relatively small water bottle sample, with not

TABLE II

PLANKTON. MIDDLE OF TURKEYFOOT LAKE

Organisms per Liter; each Figure an Average of the Four Depth Levels

Organisms	Aug. 17, 1936	Sept. 19, 1936	Oct. 17, 1936	Nov. 14, 1936	Jan. 9, 1937	Mar. 27, 1937	April 24, 1937	May 22, 1937	June 19, 1937	July 19, 1937	Aug. 20, 1937	Sept. 18, 1937	Oct. 16, 1937
Coelosphaerium	3,650	11,169	6,531	6,700	75	38		414	2,899	3,750	4,325	544	91
Microcystis	2,325	3,344	5,881	387			1,488	242	509	1,600	1,886	95	47
Anabaena	9,612	9,331	1,419	44					4,368	42,102	6,700	874	50
Aphanizomenon	6,562	77,188	50,025	16,069	3,075	2,263	500	1,313	221,500	70,175	800	750	
Melosira	1,000	312	2,344	6,625		175	600	250	500	2,625	288	750	660
Stephanodiscus				278	513	863	400			1,900		50	100
Synedra	1,500	312	1,875	4,625	5,475	2,550	24,000	3.363	50		275	150	500
Asterionella			312	1,750	4,988	220,250	940,250	28,625	350				
Fragilaria	2,750	3,125	312	1,231	38	1,313	4,500	2,625	1,000	2.313	1,438		50
Pediastrum	75		4	5	2	51		10	4	17	2	2	7
Ceratium	3,958	1,229	171	12		2	7	92	4,760	2,301	823	73	14
Codonella			6	15	196	1,380	147				2	3	6
Polyarthra	40	51	53	56	10	20	139	237	22	255	99	116	447
Keratella	222	192	157	186	241	172	312	1,073	141	377	407	334	323
Asplancha					1	1	7	8	11		7	16	25
Synchaeta						1					41	115	24
Notholca	3	8	3	5	4	5	3	22	14	28	2	14	3
Nauplius	78	53	18	91	83	129	269	76	39	90	22	62	11
Cyclops	25	46	15	31	58	57	74	74	6	11	12	10	9
Diaptomus	15	8			3	1		16	8	4		1	2
Daphnia	10	8		3	2		10	59	5	5		1	
Bosmina		1		1	1		5	5			1	3	17

TABLE III

Plankton. Middle of Turkeyfoot Lake

Organisms per Liter; each Figure an Average of the Four Depth Levels

Organisms	Jan. 15, 1938	Feb. 19, 1938	Mar. 19, 1938	April 16, 1938	May 21, 1938	June 18, 1938	July 16, 1938	Aug. 20, 1938	Sept. 17, 1938	Oct. 15, 1938	Dec. 3, 1938	Jan. 28, 1939	Mar. 25, 1939
Coelsosphaerium		2				488	1,550	2,775	950	252			
Microcystis							600	2,800	250	85			
Anabaena						7,750	16,050	5,600	1,900	400			50
Aphanizomenon						3,500	42,250	1,900	500	250	50	250	
Melosira		1,000	250	500			500	450	400	400	7,500	1,500	350
Stephanodiscus		55	135	450	465		4	50			3,558	1,763	4,250
Synedra	14,667	4,250	10,500	135,500	750			1,250	3,850	750	12,500	63,250	27,500
Asterionella			1,500	11,750	85,250	12,750					3,350	15,500	308,000
Fragilaria		1,000		750	2,750		2,250	500	1,600		300		450
Pediastrum		1		4	21		20	8	10	4	14		
Ceratium	4		3	2	258	16,300	139	92	31	3		1	1
Codonella	11	2	11	20	12	2					14	11	75
Polyarthra	7			717	195	183	161	87	68	94	36		24
Keratella	272	116	131	448	1,033	35	1,036	118	95	104	507	504	174
Asplanchna				1		13			5	7	7		
Synchaeta							45	4	13	1		4	
Notholca							8				8		
Nauplius	607	58	27	266	119	35	24	28	31	28	80	70	39
Cyclops	807	107	86	57	100	7	6	12	9	13	52	47	16
Diaptomus			3		10	20	10	1		1	2		
Daphnia	1		1	5	10	19	1		1				
Bosmina	16	11	3	1	73	1	2		5	2	8		

so abundant a population of this diatom. However, in three collections, December, 1938, January and March, 1939, Stephanodiscus occurred in much larger numbers in the water bottle sample. Net counts were used, as the other would show a very haphazard distribution.

TABLE IV

NANNO-PLANKTON. MIDDLE OF TURKEYFOOT LAKE

Organisms per Liter; each Figure an Average of the Four Depth Levels

Organisms	Aug. 17, 1936	Sept. 19, 1936	Oct. 17, 1936	Nov. 14, 1936	Jan. 9, 1937	Mar. 27, 1937	April 24, 1937
Coelsosphaerium naeg.	...	19,813	...	...	...	...	...
Oscillatoria (small sp.)	...	...	...	...	...	...	33,250
Synedra (small sp.)	...	...	...	...	...	...	170,000
Amphora	...	...	...	...	...	...	...
Scenedesmus	500	625	1,258	1,500	...	...	8,750
Trachelomonas	1,750	8,000	3,438	2,063	...	...	...

Organisms	May 22, 1937	June 19, 1937	July 19, 1937	Aug. 20, 1937	Sept. 18, 1937	Oct. 16, 1937	Jan 15, 1938
Coelosphaerium naeg	...	...	...	...	...	...	...
Oscillatoria (small sp.)	16,688	...	...	924,500	7,725,000	50,000	...
Synedra (small sp.)	36,563	...	36,000	2,538,500	450,000	95,000	...
Amphora	...	...	...	...	...	...	...
Scenedesmus	1,875	...	913	2,275	...	2,000	...
Trachelomonas	...	...	...	21,650	3,750	15,250	1,250

Organisms	Feb. 19, 1938	Mar. 19, 1938	April 16, 1938	May 21, 1938	June 18, 1938	July 16, 1938	Aug. 20, 1938
Coelosphaerium naeg	...	...	...	...	...	21,750	...
Oscillatoria (small sp.)	...	...	...	...	...	...	...
Synedra (small sp.)	68,000	...	143,500	...	...	3,250	188,500
Amphora	...	...	...	...	...	...	...
Scenedesmus	...	...	6,250	...	...	1,500	750
Trachelomonas	6,000	3,250	10,750	1,000	500	3,350	2,000

Organisms	Sept. 17, 1938	Oct. 15, 1938	Dec. 3, 1938	Jan, 28, 1939	Mar. 25, 1939		
Coelosphaerium naeg	...	...	...	...	...	...	...
Oscillatoria (small sp.)	667,500	21,250	122,500	390,000	...	...	...
Synedra (smal sp.)	311,250	22,500	58,750	...	...	...	...
Amphora	18,982,500	225,000	...	45,000	...	...	...
Scenedesmus	1,500	...	1,500	...	...	...	...
Trachelomonas	6,250	5,500	9,000	7,750	10,250	...	...

A few of the twenty-seven genera occurred in relatively fewer samples or in smaller numbers than others of their class. They were the blue-greens Aphanocapsa and Oscillatoria (a large species), the desmid Staurastrum, the Protozoa (or Algae) Mallomonas and Dinobryon.

The remaining 22 genera of net plankton appear in condensed tables. In these (Tables II, III) vertical distribution is lost, since each figure of organisms per liter is the average of all 4 depth levels. Figures 4 to 8, made from these, show the seasonal distribution.

The six nannoplankton kinds were secured only from water bottle collections. Tables showing vertical distribution of the six genera of nannoplankton are also omitted for want of room, but a condensed table giving the average figures of organisms per liter for the vertical range of four levels appears (Table IV). One plankter, the small Coelosphaerium, was omitted; it occurred in only two collections of the twenty-six, though in large numbers. Figure 3 shows the seasonal distribution of the five nannoplankton.

Some other plankton types were occasionally found, but so sporadically that inclusion in tables and graphs would have given little information. Among those recognized were Navicula, Euglena, Phacus, Cosmarium, Closterium, Gonium, Pandorina, Glenodinium, the rotifer Chromogaster (Anapus) and Chydoris. A few scattered diatoms were not recognized. Several kinds of rotifers, maybe six, appeared as individuals, rather widely scattered, mostly in rather poor condition, and were not identified.

It should be added that Dr. Taft in minute examination of some samples, found, besides the abundant kinds, some Chroococcus, Gomphosphaeria, Coelastrum, Sphaerocystis, Crucigenia, Oocystis, Eudorina; many of these were rare, or if not for a certain sample, were in the collections as a whole.

Dr. Noland in minute examination of some samples noted besides certain abundant ones, the following zooplankton, Peridinium and uncommonly various Ciliates mostly in rather poor condition in the preserved material, including Vorticella, Campanella, Lembus, Halteria and possibly others.

VERTICAL DISTRIBUTION

The vertical distribution could be seen only in the extended tables comparing the organisms per liter in surface, 4 m., 8 m., and 12 m. water. A study of all this data showed that there was rarely a uniform distribution from top to bottom, that the differences were not of much significance, that they were not consistent, that is that sometimes numbers were larger for a higher level than a lower, and at other times were smaller for the same higher level than the lower. In the case of most blue-green algae there was a tendency, expecially in times of maxima to have more at surface and 4 m. than in deeper waters, though not quite so pronounced a difference as expected from laboratory conditions in which these blue greens would rise to the top in bottles and centrifuged water. Among the nannoplankton a few striking differences occurred. When the organisms were most abundant, the tiny Oscillatoria and the tiny Synedra, August and September, 1937, August and September, 1938, and the Amphora, September, 1938, were excessively abundant in the upper levels, and relatively few in the two deeper levels. The same was true of the small Coelosphaerium, not listed in the table. In these few cases, there was a close correlation with water temperature, the abundance going with high temperature. (See further discussion under seasonal distribution.)

SEASONAL DISTRIBUTION

The average number of organisms per liter for 22 plankton genera and separately for 5 other nannoplankton kinds were used for construction of the figures (3 to 8), as noted above. The graphs give a picture of the distribution, but it must be remembered that they are semi-logarithmic. A zero line had to be added (despite any mathematical objections), arbitrarily below the lower base line, which stands for either 1 or 10 in various graphs, and for 100 in Fig. 3.

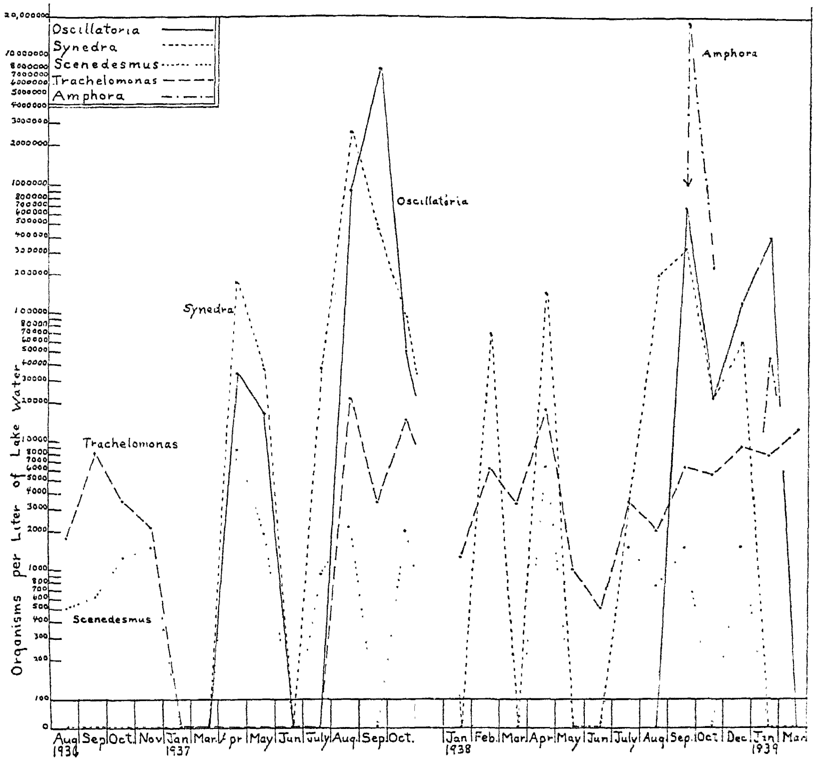


Fig. 3. Nannoplankton. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarithmic graph.

The various classes of plankton have long been recognized as having a somewhat typical cycle, with a period or two periods of maximum abundance annually, correlating approximately with the seasons. Information on this matter is summarized in texts of Whipple (1927) and Welch (1935). In the former, the seasonal climaxes are especially stressed (Chapter IX). Welch (pp. 236–239) also points out that despite seasonal periodicity there is much variation within a year and from year to year, and that instead of a taxonomic group being a unit, each plankter in the last analysis is practically a unit in itself. In the graphs presented here, each plankton kind is shown in its own curve, but with those of its own taxonomic group, so that it can be seen how closely the members of a class coincide in their pulses. It was thought that additional graphs representing total plankton of each class could be dispensed with.

CYANOPHYCEAE

The annual period of maximum development of blue-green algae is late summer. In this study the individual kinds of Cyanophyceae were seen to have their maxima not coinciding precisely and not at exactly the same time nor as large each year.

Coelosphaerium of two different types was found. One type (Tables II, III) was large, often in large colonies, though of such range of size that it might have been a mixture of C. dubium and C. kuetzingianum. Colonies always had a bright color and contributed materially to the water bloom and rose uniformly to the top of laboratory vials and in centrifuging. The other (Table IV) identified as C. naegelianum, was found only in water bottle samples in two collections. Its cells were smaller, colonies smaller and definitely of a paler color. The large Coelosphaerium (Fig. 4) attained a maximum in September in two of the three years, but was also abundant in August and even in October. It developed and declined slowly so that its season in which it thrived lasted from late June practically to November.

Microcystis was somewhat less abundant than Coelosphaerium, had a shorter period of development, but nevertheless rather similar distribution. One minor peak of development, but almost equal to the late summer peak of the year, occurred in April, 1937. (Figure 4.)

Oscillatoria of large size occurred infrequently. But in the nannoplankton graph a tiny filament identified as Oscillatoria was very abundant. In 1937 a minor peak was evident in April, followed by a complete decline, a major peak in August and September, with rapid decline in October. But the next year's distribution differed somewhat; the major peak, September, was much smaller, a great decline followed, but there was a large peak in January. (Figure 3.)

Anabaena on the whole showed consistency. The filaments were always prominent, rather long, the count being of such so-called whole filaments. Small pieces were counted as fractions. It was an important contributing cause of water bloom. Anabaena reached its peak earlier than Coelosphaerium, and attained greater numbers. In the two years of complete summer records, the peak was in July, but almost as high in August. Autumnal decline was slower than early summer increase. (Figure 4.)

Aphanizomenon was somewhat similar to Anabaena, but reached far greater numbers and was sometimes important in the water bloom. In two years the great peak was in June and July; unfortunately no record was available for those months in 1936, which had a very large peak in September with only a small decline in October. (Figure 4.)

It is evident that not alone in late August and early September when more or less water bloom appears, is the class as a whole prominent. Its season of thriving is much longer. There is a correlation with water temperature, of the class as a whole. But as noted above, Aphanizomenon which attained greatest numbers of all these listed among net-plankton, reached its greatest of all peaks one June, with somewhat less in July, and a big decline in August and more in September. The big June-July pulse was three times as high a peak as the next highest attained the preceding year in September. The third year the highest peak, one-fifth that of the highest of all, was centered in July. Water temperatures on the whole are 5° C. lower on the surface in June than in August. (See Table I, and Figure 2.) Other very abundant blue-greens, especially the small Oscillatoria of the nannoplankton, correlate their abundance more closely with the maximum temperatures.

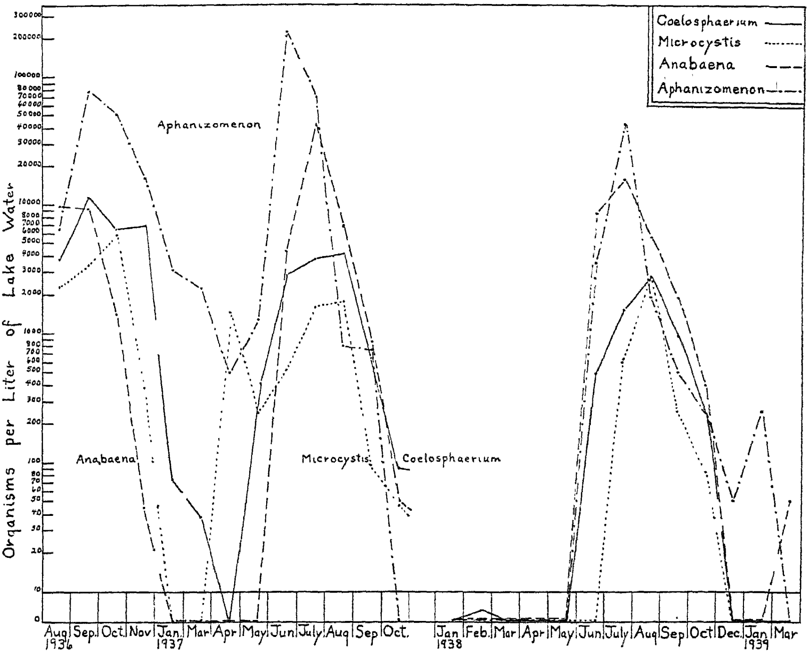


Fig. 4. Blue-green algae. Seasonal Distribution from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarithmic graph.

Vertical distribution is not exhibited in the graphs. While much of the year the algae population differed only slightly at the several levels sampled, there was relatively far more increase at the surface, and nearly as much at 4 m., than in the deeper waters, at the late summer maxima or time of the water bloom. This, as was noted in temperature chart and graph, was the time of surface temperatures of 26° to nearly 28° C., and 25° to 26° C. at 4 m., but average temperatures of 19° C. at 8 m., and less at 12 m.

DIATOMACEAE

Diatoms are generally recognized as having a striking spring maximum and a secondary late fall peak, or the two pulses reaching about equal maxima. Whipple (p. 228) lists Asterionella, Tabellaria, Melosira, Synedra, Stephanodiscus, Cyclotella, and Diatoma, as being the chief genera exhibiting spring and fall maxima.

Melosira was not found distributed seasonally in quite this manner. There was no distinct spring peak, only a fair number throughout this as in most seasons. The only distinct peaks were in November, 1936, December, 1938, with the next largest pulses in July, 1937, and February, 1938. (Figure 5.)

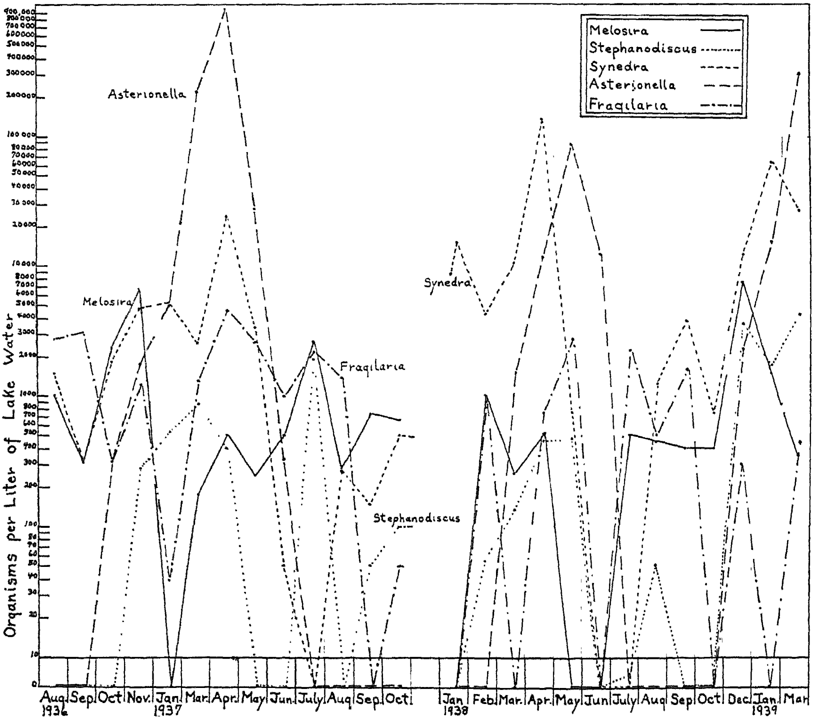


Fig. 5. Diatoms. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarthmic graph.

Stephanodiscus was also found distributed in fair quantity in many months of the year, with a fairly broad spring peak, but also a July peak one year and a winter peak, December to January. In one year a long winter and spring pulse was continuous. (Figure 5.)

Synedra of a large species was prominent in net-plankton. (Figure 5.) A much smaller species, about one-fifth as long as the other, was found only in water bottle samples and shown in nannoplankton graph. The large net-plankton species was more widely distributed during the year and common except in early summer. There was a high April period definitely each year, also large numbers in fall and one high peak January, 1939. The tiny Synedra occurred in tremendous numbers in a late summer 1937 peak, and large numbers in a spring pulse each year, with two separate peaks in spring 1938, and also an extended autumn pulse the same year. The greatest number of all attained (August, 1937), was actually eight times the number of organisms attained in the second highest peak. A re-check showed no late summer occurrence whatsoever in 1936. This tiny Synedra and one other diatom of the nannoplankton (Amphora) were the only ones which had, and then really only in the greatest maximum, a far greater number in upper than in deeper waters. (Figure 3.)

Asterionella showed the greatest spring pulses and attained the greatest total numbers of all diatoms except the tiny Amphora in its one great splurge. An outstanding peak was attained in April, 1937, though a decidedly smaller one next year and that delayed until May. The last collection made, March, 1939, showed an ascending population that probably reached a month later some figure like that of April, 1937. (Figure 5.)

Fragilaria occurred at least as uniformly throughout the year as Melosira and Stephanodiscus, though at the same time exhibiting small peaks in April and May and other minor peaks in erratic arrangement. (Figure 5.)

Amphora, a very small diatom (recorded in the nannoplankton group) was found present only in September and October, 1938, and January, 1939. Strangely, it was not even found in the similar periods in either of the other two years as another re-check showed. Of course, a plankter as small as this might have been overlooked if it occurred only as a few scattered in a counting cell, among debris and larger plankton, but any such numbers would have been irrelevant. Furthermore, the enormous maximum, 19 million, as in all other figures used in making graphs, is an average of four samples from surface to 12 m. Deeper waters had smaller numbers and surface water about twice the average number. (Figure 5.)

CHLOROPHYCEAE

Green algae were not represented by any types that were predominant in the lake plankton, though various kinds occurred in very small numbers in irregular distribution and three were found in larger numbers. Even one of these, the desmid Staurastrum, was omitted from the graphs. It occurred in just eight of the 26 monthly collections. Largest numbers were recorded in May, both in 1937 and 1938, but otherwise distribution was sporadic.

Pediastrum is recorded in Figure 6. It was found in rather small numbers but in quite a few months of the year. Only slight peaks or pulses were shown, in spring and in summer; one of August, 1936, was highest, March, 1937, was next largest and among the lesser peaks was one in December.

Scenedesmus, among nannoplankton, has peculiar distribution, with a number of peaks of which the most consistent was an April peak. There were also separate small peaks in November, 1936; August and October, 1937; and July, September and December, 1938.

PROTOZOA

Only certain flagellates were present and numbers of ciliates which were relatively rare. Dinobryon, Mallomonas, Trachelomonas, Ceratium and Codonella were followed through the collections. It is realized that several of these types are classified as algae by various algologists, but for the present purposes they may well be grouped together here. Mallomonas and Dinobryon occurred less often and are omitted from the graphs. Their distribution seemed erratic. One decided peak for Dinobryon occurred in April.

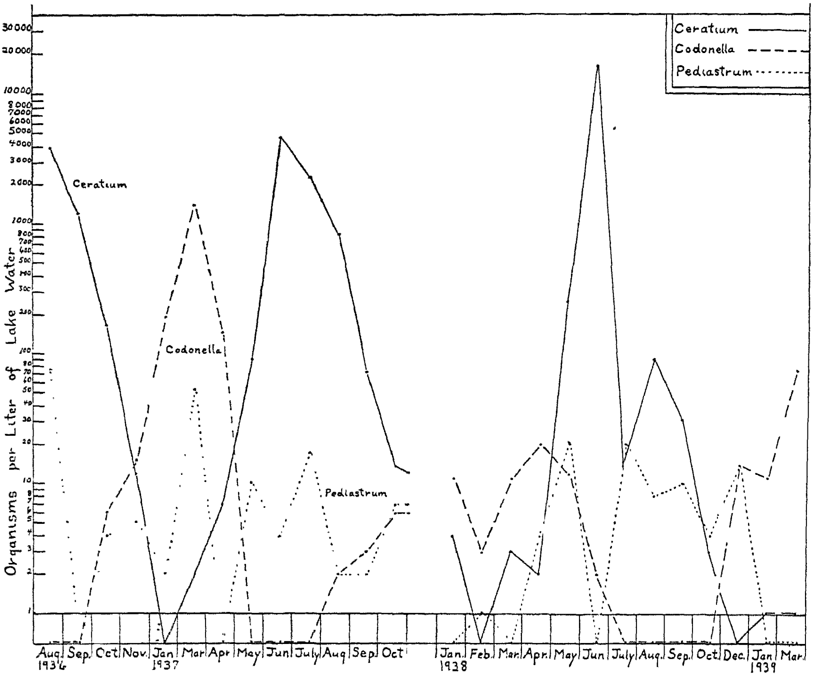


Fig. 6. Protozoa and a Green Alga. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarithmic graph.

Trachelomonas is on the nannoplankton graph (see Figure 3). The pulses were pronounced but not the same each year. An early autumn peak was most definite, but in one year a spring peak occurred, followed in fall by a gradually rising number that continued to increase somewhat through the winter and to next spring.

Ceratium (Figure 6) was a very prominent plankter, found nearly throughout the year. The great pulse occurred in a pronounced peak in June, though nearly as great a peak was reached in August when the first collections were made. The early summer pulse either continued somewhat, or repeated as another secondary pulse (August, 1938).

Codonella is a characteristic plankton ciliate having a lorica. It was present in many samples, but had a large peak in March of only one year, and minor peaks January, April, and December, and somewhat higher again in March following. (Figure 6.)

ROTIFERA

Rotifers formed a prominent group in the plankton. Rotifers are said to have their large numbers between June and November (Whipple, p. 235). Five genera were followed throughout. (Figure 7). Several other kinds, not identified, were rare or scattered. Chromogaster was recognized, but also was apparently rare.

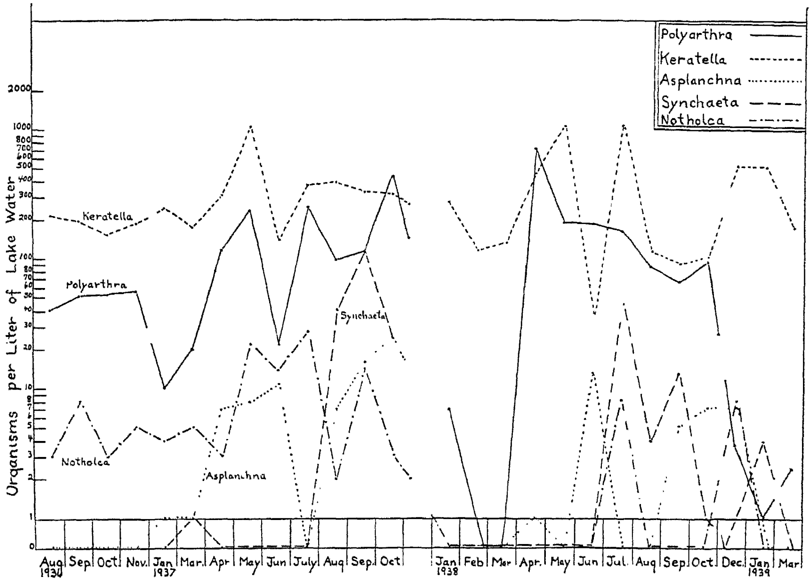


Fig. 7. Rotifers. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. Semi-logarithmic graph.

Polyarthra was found during nearly the entire year with only one considerable break in continuity in early spring one year. The highest peak occurred in one April, and this pulse decreased gradually during summer and late fall. In another year there were distinct though lesser peaks in May, July, and October.

Keratella (Anuraea) was the rotifer which was most uniformly distributed through the seasons. Increases that occurred resulted in a peak in May, and in May and July the next year, but with a quick decrease in June both years. The winter season did not show any minimum, in fact, in one winter the number ran far higher than the annual average.

Asplanchna had a far more restricted distribution, but variable. One year there was a small peak April to June and another August to October; another year a peak in June and one from October to December, whereas in another year none were found in samples of late summer and fall.

Synchaeta was likewise restricted, and numbers were small. A decided pulse occurred one September. In another year there were three, decreasing sized pulses, June, September, and January.

Notholca showed a little more continuous distribution for approximately a year with a general increase in late spring and summer but in another year it appeared less often with a slight peak in July and another in December.

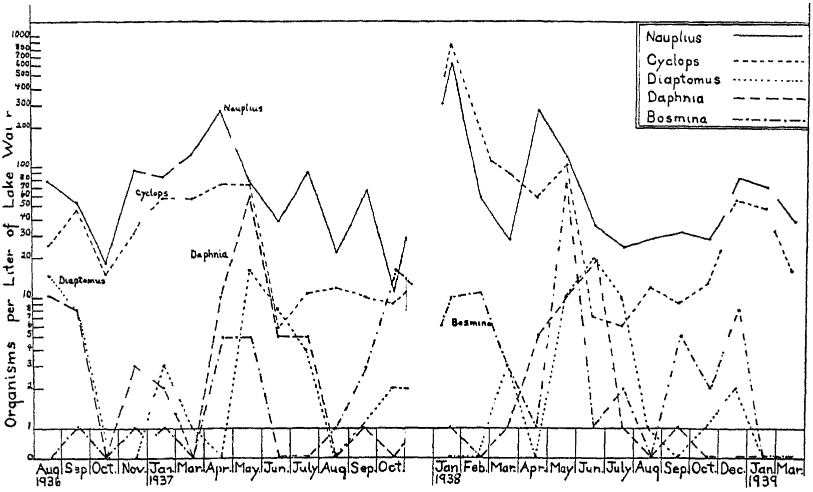


Fig. 8. Entomostraca. Seasonal Distribution, from August, 1936, to March, 1939. Organisms per liter. Each reading is an average of four depth levels. semi-logarithmic graph.

ENTOMOSTRACA

The smaller Crustacea are the largest of the normal plankton organisms, and though their numbers do not seem large, they make a prominent part of plankton life. Cyclops and their larvae, Nauplius, were really rather abundant, other types more occasional, and on the whole not very common. It is perhaps surprising that more Cladocera should not have appeared. (See Figure 8.)

Nauplius larva was found commonly during most of the year. It exhibited a number of slight pulses and declines. The most consistent peak was in April, but one January peak was far higher. Minima were in October. The Nauplius was that of Cyclops in most cases probably, though in this type of routine work it is not at all sure that Diaptomus larva was separable from Cyclops.

Cyclops had a distribution somewhat similar to Nauplius. An unusually high peak of development occurred January, 1938. Otherwise there was little consistent seasonal variation. Points of minima were in October, June and July. On the whole, the numbers were up well from the middle of the winter, through spring until May.

Diaptomus appeared in small numbers, but with decided pulses, going to vanishing points in samples after each pulse. Separate peaks were in succession in August, January, May, October, and the next March, June and December. There is at least a slight regularity in the intervals between these pulses, but they do not come at the same time from year to year.

Daphnia had, possibly accidentally, a distribution very similar to that of the Copepod Diaptomus; the pulses were, with some exceptions, practically at the same time. The highest peak was in May, 1937; one a year later in June was, however, only a third as high. Otherwise, no pulses were ascertainable. A fairly consistent low point occurred in October.

Bosmina appeared in smaller numbers than the other Entomostraca, on the whole. But there were also a few real pulses, the largest in October, 1937, a smaller one in the following February and a very large one in May.

SUMMARY

Plankton organisms were collected in one central pelagic station in Turkeyfoot Lake, from August, 1936, to March, 1939. In the 32 month period, 26 monthly collections were made. Months missed were chiefly in winter, but only once were two consecutive collections missed.

Temperature records were made and a table and graph of much of this data is presented.

Tests of dissolved O_2, CO_2, and pH colorimetric tests were made and a brief summary of this data is presented.

Plankton was collected by trap-net and water bottle and counts made under low power of all organisms as far as size permitted, from both collecting devices. A few kinds of real nannoplankton were secured only from the water bottle. Of those collected by both devices, the net counts were found most satisfactory for most of the plankton, but the water bottle counts best for most diatoms and one of the blue-greens.

Of many plankton kinds, 27 genera regarded as net-plankton and six nannoplankton were tabulated. Of the former, 22, and of the latter, 5 are presented in condensed tables and graphs.

Vertical distribution was studied, samples having been from four levels in all collections. No definite or consistent trends

in the vertical range could be ascertained, for any groups except in the case of some blue-greens and also of two of the smallest diatoms, and then only in times of great maxima, which were in a late summer water bloom when surface water temperatures were highest.

Seasonal distribution was the main objective. A set of six graphs, each graph comprising the group of related types, shows the seasonal cycle with pulses for all the main plankton genera. The classes had, as far as classes do have any uniform maximum pulses in definite seasons, the expected seasonal arrangement, including most prominently the one great late summer development of the blue-greens and the prominent spring pulse of diatoms. But in most groups there were many pulses, different for different genera, irregular through the seasons and differing somewhat in successive years.

LITERATURE CITED

Kraatz, W. C. 1931. A Quantitative Net-Plankton Survey of East and West Reservoirs, near Akron, Ohio. Ohio Jour. Sci., Vol. XXXI, No. 6, pp. 475–500.

1940. A Comparison of Plankton Counts from the Trap-Net and Water Bottle Centrifuge Techniques. Ohio Jour. Sci., Vol. XL, No. 3, pp. 151–161.

Ricker, Wm. E. 1938. On Adequate Sampling of the Pelagic Net Plankton of a Lake. J. Fish Res. Bd. Can. 4 (1), pp. 19–32.

Standard Methods of Water Analysis. 1923. 5th Ed. American Public Health Association.

Welch, Paul S. 1935. Limnology. McGraw-Hill Book Co., pp. 1–471.

Whipple, G. C. 1927. The Microscopy of Drinking Water. 4th Ed. John Wiley and Sons, pp. 1–586.

Adsorption

In a small book, "Some Problems in Adsorption," published by the Cambridge University Press, J. K. Robertson has presented a rather complete review of this very interesting field to which he himself has made a very definite contribution. The work is divided into seven chapters, preceded by an author's preface. In the preface the author presents a brief account of events that led up to the experimental investigations, the discussion of which is contained in the seven chapters of the book. In chapter I the experimental methods are presented, and succeeding chapters are devoted to heat of adsorption; formation of adsorbed films; evaporation processes and the formation of atomic hydrogen; effects of dipole interaction and properties of oxygen films on tungsten.

The discussion is presented in a very readable style which can be grasped by anyone with an intermediate training in physics. It can be recommended very sincerely to students of physics who are interested in obtaining an *introductory* knowledge of the problems of adsorption.—*H. H. Nielsen.*

Some Problems of Adsorption, by J. K. Robertson. 119 pp. Cambridge, at the University Press; in New York, the Macmillan Co., 1940. $2.00.

SEBEKIA OXYCEPHALA (PENTASTOMIDA) FROM FLORIDA FISHES AND SOME NOTES ON THE MORPHOLOGY OF THE LARVAE

CARL ERNEST VENARD

and

RALPH V. BANGHAM

Sebekia oxycephala (Diesing) Sambon, 1922, lives in the lungs, trachea, and pharynx of crocodiles and alligators which inhabit South America and the southern portion of North America. Developmental stages have been reported (Heymons, 1935) from fishes, snakes, a lizard, and crocodiles. The genus Sebekia contains six additional species, all of which are parasitic in alligators and crocodiles. *S. oxycephala* is not very well known and there is less information on the other species.

In 1928 Holl created a new genus and a new species for linguatulids from *Eupomotis gibbosus* (L.) and *Ameiurus natalis* (Le Sueur) taken from an artificial lake near Gibsonville, North Carolina. He called his specimens *Bdukus ichthyius*. Heymons believes that Holl's species is the larval form of *Sebekia oxycephala*.

Bangham (1939) studied the parasites of fish, particularly the sunfish family Centrarchidae, collected near Englewood, Florida. Larval linguatulids, which resembled *Bdukus ichthyius*, were found. They were different, however, in the distribution of the stigmata and Doctor Holl very kindly loaned us two specimens of *B. ichthyius* for comparative studies.

The internal anatomy of *Sebekia oxycephala* is very imperfectly known. Heymon's illustration of a larva deals with external features; his illustration of the anterior portion of an adult male supplies information on the sexual organs. The material collected by Bangham furnishes additions to our knowledge of the anatomy, geographical distribution, and hosts of *Sebekia oxycephala*.

ANATOMICAL STUDY

Thirty-one parasites were collected and preserved in five per cent formalin. Some were killed in their cysts and others were dissected out of them. The specimens were stained in Delafield's haematoxylin and mounted in balsam on slides. The stain entered through the mouth and anus to some extent, but a few specimens had been injured and the chitinous covering was not intact. The internal organs in such individuals were favorably colored for observation.

Within its cyst the larva assumes a characteristic attitude. The entire body is ventrally flexed and the abdominal portion is coiled underneath the head (Fig. 3). Young individuals show no evidence of segmentation and the head is large in proportion to the remainder of the body. The hooks and internal organs are incompletely developed. The cysts are 2.6 mm. in diameter and white in color. They were found at the surface of the liver under the peritoneum and in the mesenteries.

Completely developed encysted individuals, when removed from their coverings, are 3 mm. to 5.5 mm. in length and 0.4 mm. to 0.79 mm. in greatest width. In general, males are smaller than females. The total number of segments is from 64 to 68. The musculature of the body wall and hooks is functional and the shape of the body and position of the hooks show some variation in the different specimens. The widest part of the body is at the middle and it gradually diminishes in diameter toward the posterior end which is blunt. The terminal segment is of the same length as an individual segment anterior to it, and bears the anus at its tip. Towards the head the diameter becomes less but there is no definite neck. The first annulus is a very short distance posterior to the mouth.

The head bears the four hooks and mouth as conspicuous structures (Figs. 1 and 4). The hooks may be extended or retracted. They are similar in size and shape (Fig. 8).

The stigmata are found on all segments and the head. They are particularly evident in cuticula which has become loosened from the underlying tissues. The stigmata do not occur in definite rows as described and illustrated by Holl (1928) and Heymons (1935) for the specimens they studied. Their arrangement is irregular (Fig. 7) and there is no definite pattern. This irregularity is greater in younger than in older specimens and is easier to see in relaxed than in contracted individuals.

The intestine and lateral glands are similar in both sexes. The stomadaeum is quite short, extending below the mouth a distance equivalent to one segment. The proctodaeum is much longer and is found

---

EXPLANATION OF PLATE

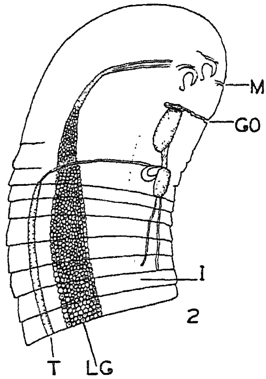
Fig. 1. Head end of a well cleared male, ventral view.
Fig. 2. Anterior end of male, lateral view.
Fig. 3. Encysted male.
Fig. 4. Head end of female, ventral view. The hooks are well extended and no internal morphology is visible. Figures 1, 4 and 5 are drawn at the same magnification.
Fig. 5. Posterior end of a female, lateral view.
Fig. 6. Segment from Holl's specimen number 940, showing distribution of the stigmata.
Fig. 7. Segment from a Florida specimen.
Fig. 8. Lateral view of a hook.

ABBREVIATIONS:

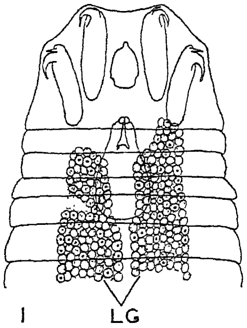
GO—Genital opening.
I—Intestine.
LG—Lateral gland.
M—Mouth.
T—Testis.
U—Uterus.

Sebekia oxycephala
Venard and Bangham

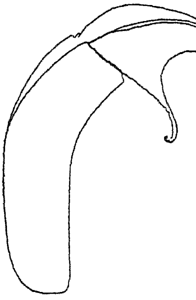
PLATE I



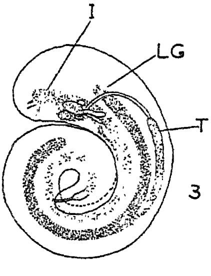
2



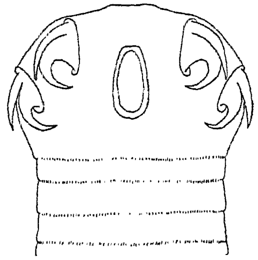
1



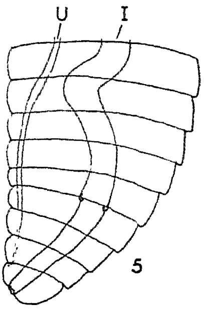
8



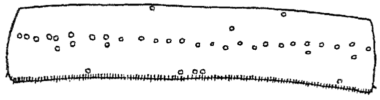
3



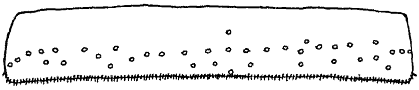
4



5



6



7

in the last four segments. The mid-intestine is of fairly uniform diameter although largest a short distance below the mouth. It pursues a rather winding path through the body. The pair of lateral glands extends, one on each side of the body, from the first segment to the fiftieth or fifty-fifth. The glands are voluminous and their cells are large. Two ducts emerge from the glands at their anterior ends and bend towards the bases of the hooks.

The sexual organs of the male (Fig. 2) are distinct but the individual structures are not named since the connections between them cannot be determined with certainty. The organs, in an earlier stage of development where they appear quite different in shape and arrangement, are evident in a young encysted specimen (Fig. 3).

The sexual organs of the female cannot be seen except for a dorsally placed ovary and a ventral vagina. The sexual opening appears to be on the last segment and anterior to the anus (Fig. 5).

HOSTS

Eighteen fish were infected with one to six linguatulids which were usually encysted in the mesenteries. The species of fish and the numbers of each that were infected are:

1 Bowfin, *Amia calva* Linn.;
1 Mosquito-fish, *Gambusia affinis holbrookii* (Girard);
2 Black-spotted sunfish, *Sclerotis punctatus punctatus* (Valenciennes);
1 Florida long-eared sunfish, *Xenotis megalotis marginatus* (Holbrook);
6 Stump-knocker, *Eupomotis microlophus* (Günther);
5 Warmouth bass, *Chaenobryttus gulosus* (Cuvier and Valenciennes);
2 Black crappie, *Pomoxis sparoides* (Lacépède).

The total numbers of these fish examined are, in the order given above, 21, 143, 18, 14, 49, 90, and 79. The infected fish were obtained from small pools and ponds near the channels of large streams. Fish were also taken from the Myakka and Peace Rivers, Lake Okeechobee and Everglades Canals but none of them carried this parasite.

Species of fish in which linguatulids were not found and the numbers of each examined are:

Lepisosteus platyrhincus De Kay, 82;
Dorosoma cepedianum (LeSueur), 7;
Erimyzon sucetta sucetta (Lacépède), 70;
Opsopoeodus emiliae Hay, 25;
Notemigonus crysoleucas bosci Valenciennes, 43;
Ictalurus lacustris punctatus (Raf.), 13;
Ictalurus catus (Linn.), 8;
Ameiurus natalis (LeSueur), 45;
Ameiurus nebulosus marmoratus (Holbrook), 22;
Schilbeodes gyrinus (Mitchill), 1;
Esox niger LeSueur, 10;

Fundulus grandis Baird and Girard, 8;
Fundulus majalis (Walbaum), 10;
Fundulus similis (Baird and Girard), 24;
Fundulus notatus (Raf.), 2;
Fundulus chrysotus (Günther), 84;
Fundulus cingulatus (Cuvier and Valenciennes), 16;
Fundulus seminolis Girard, 14;
Floridichthys carpio carpio (Günther), 3;
Jordanella floridae Goode and Bean, 70;
Cyprinodon variegatus variegatus Lacépède, 6;
Heterandria formosa Agassiz, 21;
Mollienesia latipinna LeSueur, 93;
Trinectes maculatus (Raf.), 4;
Menidia beryllina atrimentis Kendall, 10;
Labidesthes sicculus vanhyningi Bean and Reid, 17;
Mugil cephalus Linn., 6;
Huro salmoides (Lacépède); 86;
Helioperca macrochira (Raf.), 104;
Enneacanthus gloriosus (Holbrook), 12;
Elassoma evergladei Jordan, 1;
Centropomus undecimalis (Bloch), 4;
Eucinostomus gula (Cuvier and Valenciennes), 13;
Dormitator maculatus (Bloch), 14;

These fish were identified with the aid of the key to the fresh-water fishes of Florida by Carr (1936).

Due to the fact that *Sebekia oxycephala* has been found in many hosts, the absence of this parasite from the species of fish listed above would probably indicate lack of opportunity of becoming infected rather than resistance to infection.

DISCUSSION

A comparison of the specimens from Florida with specimens of *Bdukus ichthyius* leaves no doubt that they are identical. They agree in all details, but since the distribution of the stigmata is not the same as the published account for *B. ichthyius*, comment on this discrepancy is necessary. The stigmata of *B. ichthyius*, in general, form a circle around each segment as Holl has described. However, they also occur over the entire surface of most segments. This fact is indicated in Figure 6 which is drawn from one of Dr. Holl's specimens. Segments which are contracted show a fairly even row of openings. This is due to the fact that those openings near the middle of the segment remain open whereas the others are either closed or otherwise obscured from view.

Heymon's illustration of the larva of *Sebekia oxycephala* creates the impression that the stigmata on each segment occur in a single row, but close inspection reveals that these rows are very irregular and approach the condition described above.

There is no doubt that the larva which Heymons calls *S. oxycephala* is identical with *Bdukus ichthyius*. If these linguatulids actually are larvae of *S. oxycephala*, then *B. ichthyius* becomes a synonym since the adult was named first. The identity of these larvae as *Sebekia oxycephala* is suggested by the structural similarity between the larvae and the adults and a correspondence in their geographic distribution. The specimens from Florida fishes yield considerable information to support this contention.

SUMMARY

Linguatulid larvae, identical with *Bdukus ichthyius* Holl, 1928, and secured from Florida fishes, have been studied. Heymon's opinion that *B. ichthyius* is the larval form of *Sebekia oxycephala* (Diesing) Sambon, 1922, is supported. Comments are made on the morphology and ecology of this species, including the reporting of seven new fish hosts.

REFERENCES

Bangham, R. V. 1939. Parasites of Centrarchidae from Southern Florida. Trans. Am. Fish. Soc., 68: 263–268.

Carr, A. F,, Jr, 1936. A key to the fresh-water fishes of Florida. Proc. Fla. Acad. of Sci., 1: 72–86.

Heymons, R. 1935. Pentastomida. Bronn's Klassen und Ordnungen des Tierreichs. 5 Band, 4 Abteilung, 1 Buch.

Holl, F. J. 1928. A linguatulid parasite from North American fishes. Journ. Parasitol., 15: 63–66.

More Haldane

The prolific Mr. Haldane has collected into one volume some seventy short articles which had previously appeared in *The Daily Worker*. They cover a wide range of scientific subjects, from food to stars. Some are very well written and of extreme interest; others apparently were written just in time to catch the Thursday dead-line. Mr. Haldane's opinion of Mr. Haldane has not suffered as the years have passed.—*L. H. S.*

Science and Everyday Life, by J. B. S. Haldane. 284 pp. New York, the Macmillan Co. 1940. $2.00.

THE ALIMENTARY TRACT OF VESPULA MACULIFRONS BUY.

(HYMENOPTERA: VESPIDAE)

ROBERT THOMAS MITCHELL
Department of Zoology and Entomology,
Ohio State University,
Columbus, Ohio

Colonies of the common yellow jacket, *Vespula maculifrons* Buy., are subterranean. The nest is usually in a bank of earth that is elevated from surrounding ground, from which location the drainage of water is good. The normal food for the species consists of juices and pulp of well-ripened fruit, meats, and soft-bodied insects. Unlike the honey-bee, the yellow jacket neither collects nor eats pollen.

Observations made at the very outset of the work upon the gross anatomy of the digestive tract revealed its similarity to that of the honey-bee. The author intends therefore in several instances to compare the alimentary canal of this wasp with the canal of the honeybee. As the basis for comparison the author will use the work of Snodgrass as presented in his "Anatomy and Physiology of the Honeybee" (8).

The material used for the study consisted of seventy-five workers from a single colony in Columbus, Ohio. These were collected in October after a killing frost and about two weeks previous to the hibernation period for the queen and the termination of the colony.

The author wishes to express his sincere appreciation for the helpful suggestions and criticism of Doctor C. H. Kennedy under whose direction this work was undertaken.

TECHNIQUE

Immediately after being killed, the body wall of some of the specimens was cut along the dorsal median line and of others along the ventral median line. The insects were then placed in Kahle's solution for twenty-four hours for fixation of the tissue, after which time they were stored in 70 per cent alcohol. Parts of the tract for sectioning were dissected, stained in borax carmine, cleared in cedar oil and then imbedded in paraffin blocks. Sections three to five microns thick were cut from the block and were then stained with Haemalum (Mayer's newer formula) for nuclei and Fast Green FCF stain for the cytoplasm and cell walls.

THE GROSS ANATOMY OF THE DIGESTIVE TRACT

The alimentary canal is approximately one and one-half times the length of the insect body (Pl. I, Fig. 1). The stomodeum or fore-intestine, which is of ectodermal origin, consists of four structures: namely, the pharynx, oesophagus, crop, and proventriculus.

The Pharynx. The pharynx, situated just posterior to the mouth, is triangular in shape. Around its anterior border is a heavily sclerotized strip. The upper surface of the pharynx possesses a rectangular lamella which is rounded at the end and bears many simple hairs. The pharynx extends dorsally to a point above the level of the attachments of the antennae where it narrows to the diameter of the oesophagus.

The Oesophagus. The osesophagus is a straight narrow tube extending posteriorly from the end of the pharynx through the foramen magnum into the thorax. Through the prothorax and mesothorax the oesophagus is completely surrounded by the thoracic salivary glands. From the mesothorax it progresses in a straight line through the metathorax and the petiole of the insect body, at which point it enters the abdomen. Here the tube widens considerably, forming the crop, which among the bees is termed the honey stomach. (Pl. I, Fig. 1, and Pl. II, Fig. 1.)

The Crop. The size and position of many of the organs in the abdomen vary according to the process of digestion in progress at the time the insect is killed. The crop (Pl. I, Fig. 1) occupies the median part of the first abdominal segment and the anterior portion of the second segment. The crop is capable of great distension; and when it is expanded, the walls of the crop are thin enough to render the food within visible. When the crop is thus enlarged, one can see the proventriculus or gizzard protruding anteriorally into the lumen of the crop. (Pl. II, Fig. 1.)

The Proventriculus. The opening into the proventriculus is X-shaped, indicating the presence of four muscular lips between which the food must pass. The posterior third of the gizzard narrows rapidly to form a short narrow cylindrical peduncle. A tube, the oesophageal valve, projects caudad from the proventriculus through the middle of the ventriculus for approximately one-third the length of the stomach. (Pl. II, Figs. 1 and 2.)

The Ventriculus. The ventriculus or stomach (Pl. I, Fig. 1) is the most conspicuous organ of the entire digestive tract. It varies in respect to position, but in general, it extends from the second abdominal segment to the fifth and along its course forms two loops, one in the second abdominal segment and the other in the third. The ventriculus is annulated, light rings being present where the epithelium within is folded and dark where the epithelium is but a single layer thick and the stomach contents can be seen through it.

A sharp bend occurs at the posterior end of the stomach where the Malpighian tubules enter the pyloric valve.

The Malpighian Tubules. The entrance of the Malpighian tubules into the tract marks the end of the mesenteron or mid-gut and the beginning of the proctodeum or hind-gut. The Malpighian tubules (Pl. I, Figs. 1, 2, 5, 6, and Pl. II, Fig. 1) numbering one hundred or more, are greatly intertwined and wound about the base of the ventriculus and about the intestine. The tubules are very long, being for the most part two-thirds as long as the ventriculus. Each one is attached singly on the circumference of the valve. The distal ends of the tubules lie free in the body cavity.

The Small Intestine. At the end of the pyloric region the tract becomes reduced to about a third of the diameter of the valve. The small intestine (Pl. II, Fig. 1) is marked longitudinally by six light and dark stripes, the light stripes corresponding to the six folds of the epithelium within. The small intestine never follows a straight course but is invariably curved and looped in various ways.

The hind end of the small intestine is indicated by the termination of the previously mentioned stripes, and here the tract becomes greatly enlarged, forming the rectum.

The Rectum. The rectum (Pl. I, Fig. 1, and Pl. II, Fig. 1) like the crop is capable of considerable distention. When not distended the rectum is somewhat depressed; but when it is expanded, it is almost round. The presence of six rectal pads within the rectum is indicated by six white areas shaped like double convex lenses situated longitudinally and extending nearly one-half the length of the rectum. From its middle the rectum tapers to a slender tube which opens at the anus.

There is no decided difference between the external appearance of the alimentary tract of *Vespula maculifrons* and that of the honeybee. A minor difference that was noted is in regards to the rectal pads, which in the honeybee from external appearance are much more narrow and shorter than those in the yellow jacket.

THE HISTOLOGY OF THE ALIMENTARY TRACT

The Oesophagus. The walls of the oseophagus are very muscular, there being a thick layer of both longitudinal and circular muscles. The latter encloses the former. The epithelium is evidenced only by the presence of nuclei scattered within the thick convoluted intima.

The Crop. The structure of the crop (Pl. I, Fig. 3) is fundamentally the same as that of the oesophagus, but the convoluted chitinous intima is much thicker, almost obliterating the lumen. The similarity of structure between these two organs is expected, since they are both of ectodermal origin, being formed by an invagination of the ectoderm of the anterior portion of the embryo, and since the crop is merely an enlargement of the posterior portion of the oesophagus.

The Proventriculus. The proventriculus is of ectodermal origin likewise but differs markedly from the structure of the two previous organs of the stomodeum. The anterior opening of the proventriculus is X-shaped, made so by the presence of four thick columns of longitudinal muscle. (Pl. I, Fig. 4.) The longitudinal muscles of the crop diverge upon reaching the proventriculus and assume two different positions. (Pl. II, Fig. 2.) Some strands turn inward and connect with the thick columnar layers, accompanied in like manner by the circular muscles which form in thick layers around the columns of longitudinal muscles. Other strands of longitudinal muscle continue along the exterior of the proventriculus, making three muscle layers in the proventriculus, a thin layer of longitudinal muscle along the exterior and a thick layer of circular muscles which encircle the third set or inner thick longitudinal muscles. It is from the base of the crop therefore that the order of muscle layers is reversed. This new order, with longitudinal muscles exterior to circular muscles, extends from this point to the end of the alimentary canal.

In the honeybee Snodgrass states that the circular muscles cease at the rear end of the crop and that a new layer of circular muscles arises in the muscular columns of the proventriculus. In *Vespula* these circular muscles are a continuation of the circular muscles of the crop.

Entad to the longitudinal muscle column is a single layer of epithelium evidenced only by nuclei that lie in a straight line, the cell walls not being clearly defined. A thick, dense, and not so convoluted layer of intima lines the lumen of the gizzard. Chitinous projections or spines exist along the intima part of the way through the proventriculus.

The thick layers of longitudinal muscles taper toward the posterior end of the gizzard and finally disappear entirely at the oesophageal valve. The thick layers of circular muscles also taper toward the oesophageal valve but instead of vanishing continue to comprise a part of the musculature of the ventriculus.

The Oesophageal Valve. The oseophageal valve (Pl. II, Fig. 2, OES. V), a prolongation of the epithelium and intima of the proventriculus, projects one-third of the way through the stomach. At the distal end of the prolongation the epithelium of the valve becomes joined to an outgrowth of the epithelium of the ventriculus. This strip of ventricular epithelium one layer thick progresses anteriorally adjacent to the epithelium of the valve until it arrives at a point opposite to the first annular ring, where it turns outward and the cells become attached to the main portion of the epithelium of the stomach.

The Ventriculus. The epithelium of the ventriculus lies in regular sinuous folds, each annular ring visible from the exterior corresponding to a fold in the epithelium. (Pl. III, Fig. 1.) The epithelium is not so irregular as in the honeybee. The epithelium rests on a thin basement membrane. The cells are columnar in shape and rounded at the apex. Those at the tips of the folds projecting into the lumen tend to be larger than the rest of the cells. The nuclei are very conspicuous and lie either in the middle of the cell or toward the base, rarely toward the tip of the cell. Circular muscles encircle the stomach close to the basement membrane and can be found lying between the folds of the epithelium. A layer of longitudinal muscle borders the stomach, and in some instances a thin peritoneum joins these muscles.

Surrounding the food particles in the lumen of the stomach may be seen one to several peritrophic membranes. These membranes are formed from a gelatinous-like secretion of the ventricular epithelium. (Pl. II, Fig. 3.) The free ends of the epithelium projecting into the lumen become filled with the material and become greatly enlarged and club-shaped. The cell wall then bursts, and the secretion is emitted.

The substance thus secreted coagulates on its ental surface next to the food to form the thin film or peritrophic membrane. In the posterior region of the ventriculus there may be six or more peritrophic membranes present at one time. In the anterior portion they are fewer in number. At any time a peritrophic membrane is being laid down in some section of the ventriculus. Some cells are in active secretion while others remain in a different stage of the process. (Pl. III, Fig. 1.) After being formed, the membranes evidently pass along the tract with the food and pass out the anus as a sheath around the feces, which is characteristic of this type of peritrophic membrane that Wigglesworth terms "Type i." (12).

The presence of chitin, detected in the peritrophic membrane of the honeybee by Campbell (3), is the basis for the assumption that the peritrophic membrane must arise from the oesophageal valve, since only epithelium of ectodermal origin has been credited with the ability to secrete chitinous substances. In some insects such as *Sciara* (2), other Diptera, and earwigs (12) the peritrophic membrane is of ectodermal origin, but for the peritrophic membrane in the honeybee and the wasp evidence is sufficient to conclude that the peritrophic membrane arises from the ventricular epithelium, which is generally said to be of mesodermal origin. We must assume then, since chitin has been detected in the peritrophic membrane of the honeybee, that the epithelium of the ventriculus is capable of secreting chitinous material.

The epithelium of the ventriculus secretes not only the substance for forming the peritrophic membrane but also some nucleated bodies which probably contain digestive enzymes. (Pl. II, Fig. 3.)

Regenerative epithelial cells are rare in *V. maculifrons*. A few were found occurring singly or in pairs at the base of a fold in the epithelium. Near the posterior end of the stomach, where the epithelium is less folded and where the cells are longer, a few nidi were found where three or four regenerative cells might occur. (Pl. III, Fig. 3, RC.)

The posterior extremity of the stomach is marked by the entrance of the Malpighian tubules into the tract and by termination of the gelatinous secretion at the inner edges of the cells.

The Malpighian Tubules. The Malpighian tubules are composed of large cells with large and distinct nuclei. The inner surface of the epithelium is smooth, and the cells bulge out into the lumen. These cells rest on a conspicuous basement membrane. (Pl. I, Figs. 2 and 6.)

The Pyloric Valve. Beyond the point of the entrance of the tubules the epithelium is composed of large cuboidal cells with large nuclei. There are both longitudinal and circular muscles present, the former existing as only one layer but the latter increasing in abundance and becoming heavily massed to form a sphincter of the valve. The extremities of the pyloric region are marked by the existence of short and sharp spine-like projections upon the intima on the inner surface of the epithelium. These projections are especially abundant in areas where there appears to be an extra thick layer of intima. In Plate III, Fig. 3, S, the spines have been enlarged beyond their relative size to make them visible upon reproduction.

It is doubtful whether these spines have any definite function. It has been suggested to the author that they may be traces or remnants of the process of the tearing apart of the tissues in this area as the insect passed from the larval stage with a closed hind-gut into the adult stage in which the hind-gut is functional.

The Small Intestine. The epithelium of the small intestine (Pl. III, Figs. 3, 4 and 5) is thrown into six longitudinal folds, occurring as a single layer of cells. It possesses a layer of intima on its free surface. The nuclei are large and round and located near the bases of the cells. Snodgrass records no longitudinal muscle in the small intestinal of the honeybee, but in the yellow jacket there are two muscular layers, an inner layer of circular muscles and an outer one of longitudinal muscles.

The Rectal Valve. This valve is marked by an increase in the number of circular muscles and by a change in shape of the epithelial cells, which become elongate and lie in a double layer. (Pl. III, Fig. 4.)

The Rectum. The longitudinal muscle along the remaining portion of the tract seems to be discontinuous. It is present as an outer layer of muscle along just the anterior portion of the rectum. There is no evidence of a longitudinal muscle again until the tract approaches the anus. The circular muscle exists as a single layer around most of the rectum and then occurs in several layers near the anus. Unlike the rectal pads in *Apis* and the bumblebee (10) there is no lumen. (Pl. III, Figs. 2 and 4.) The cells of the outer layer of epithelial cells are cuboidal and devoid of intima and lie adjacent to the cells of the internal layer, which are large and elongate and possess a heavy chitinous intima. The function of these rectal pads is not definitely known. They may be glands that secrete a substance into the rectum, or they may be structures that draw water from the execrement.

LITERATURE CITED

(1) **Bordas, L.** 1894. Appareil glandulaire des Hymenopteres. 1re These. L'Academie de Medecine. Paris. 362 pp., 11 pls.

(2) **Butt, F. H.** 1934. The origin of the peritrophic membrane in *Sciara* and the honey bee. Psyche 41: 51–56. 1 pl., 4 figs.

(3) **Cambell, F. L.** 1929. The detection and estimation of insect chitin. Ann. Ent. Soc. Amer. 22: 401–426. 1 fig.

(4) **Duncan, C. D.** 1939. A contribution to the biology of North American Vespine Wasps. Stanford University Press. Stanford Univ., Calif. 272 pp., 54 pls., 255 figs.

(5) **Green, T. L.** 1931. The alimentary canal in the common wasp, (*Vespa vulgaris*). Proc. Zool. Soc. London, 1931. Pp. 1041–1065. 14 figs., 1 pl.

(6) **Kennedy, C. H.** 1932. Methods for the study of the internal anatomy of insects. Mimeo. H. L. Hedrick, Columbus, Ohio.

(7) **Nelson, J. A.** 1915. The embryology of the honey bee. Princeton Univ. Press. Princeton N. J. 282 pp., 95 text-figs., 6 pls., 15 figs.

(8) **Snodgrass, R. E.** 1925. Anatomy and physiology of the honeybee. McGraw-Hill Book Co., New York. 327 pp., 108 figs.

(9) **Snodgrass, R. E.** 1935. Principles of insect morphology. McGraw-Hill Book Co., New York. 667 pp., 319 figs.

(10) **Swingle, M. C.** 1927. The alimentary tract of the common bumblebee. Ohio Jour. Sci., 27: 219–231. 3 pls., 18 figs.

(11) **Wigglesworth, V. B.** 1930. Formation of the peritrophic membrane. Quart. Jour. Micro. Sci., 73: 593–616.

(12) **Wigglesworth, V. B.** 1939. The principles of insect physiology. E. P. Dutton & Co., New York. 434 pp., 316 figs.

EXPLANATION OF PLATES

PLATE I

Fig. 1. Dorsal view of alimentary tract, showing relative size and position of parts. Malpighian tubules shortened, showing only point of origin.
Fig. 2. Longitudinal section through a Malpighian tubule.
Fig. 3. Cross section through the crop.
Fig. 4. Cross section through the proventriculus.
Fig. 5. Cross section through the pyloric valve. (Semi-diagrammatic.)
Fig. 6. Cross section through a Malpighian tubule.

PLATE II

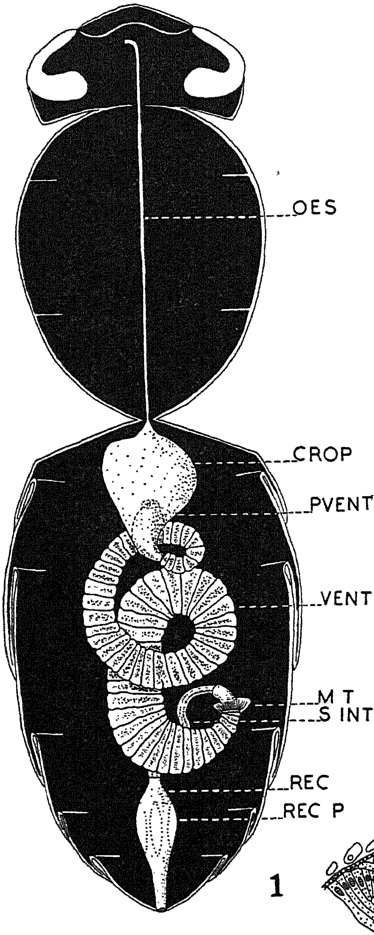
Fig. 1. Alimentary tract removed and straightened, showing relative dimensions of parts.
Fig. 2. Longitudinal section through the oesophageal valve, the valve considerably shortened. (Semi-diagrammatic.)
Fig. 3. Portion of cross section through the ventriculus, showing formation of the peritrophic membrane.

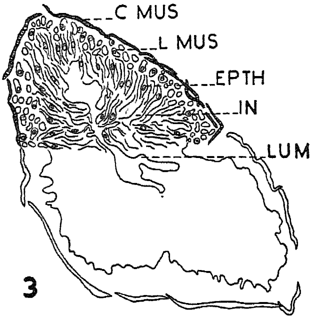
PLATE III

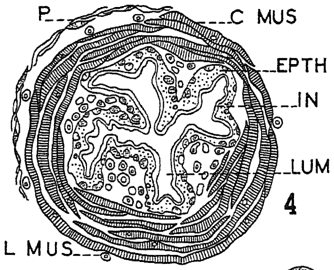
Fig. 1. Longitudinal section through portion of the ventriculus.
Fig. 2. Cross section through mid-section of the rectum.
Fig. 3. Longitudinal section through the pyloric valve.
Fig. 4. Longitudinal section through the rectal valve.
Fig. 5. Cross section through the small intestine.

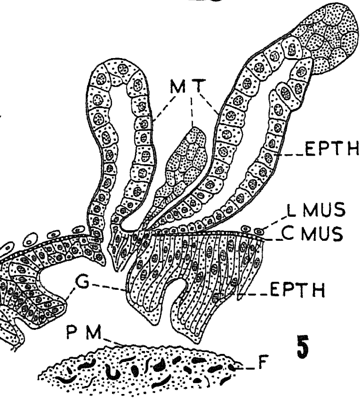
KEY TO THE SYMBOLS USED WITH THE FIGURES

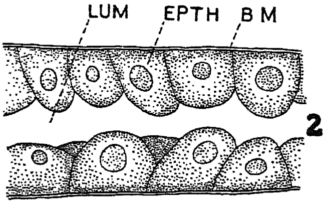
B M—Basement membrane.
C MUS—Circular muscle.
EPTH—Epithelium.
F—Food particles.
G—Secretion of epithelium.
IN—Intima.
L MUS—Longitudinal muscle.
LUM—Lumen.
M T—Malpighian tubule.
OES—Oesophagus.
OES V—Oesophageal valve.
P—Peritoneum.
P M—Peritrophic membrane.
PVENT—Proventriculus.
PYL V—Pyloric valve.
R C—Regenerative cell.
REC—Rectum.
REC P—Rectal pad.
S—Spine.
S INT—Small intestine.
VENT—Ventriculus.

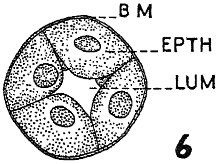

OES
CROP
PVENT
VENT
M T
S INT
REC
REC P
1

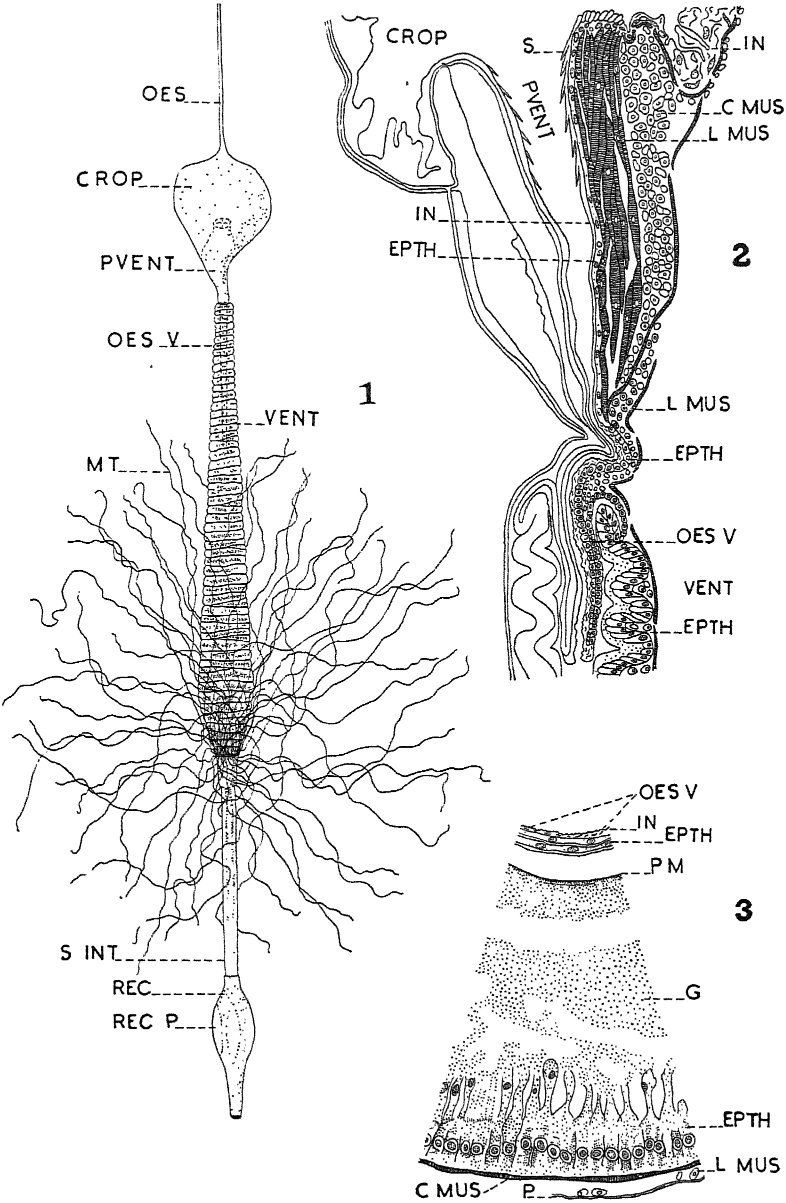

C MUS
L MUS
EPTH
IN
LUM
3

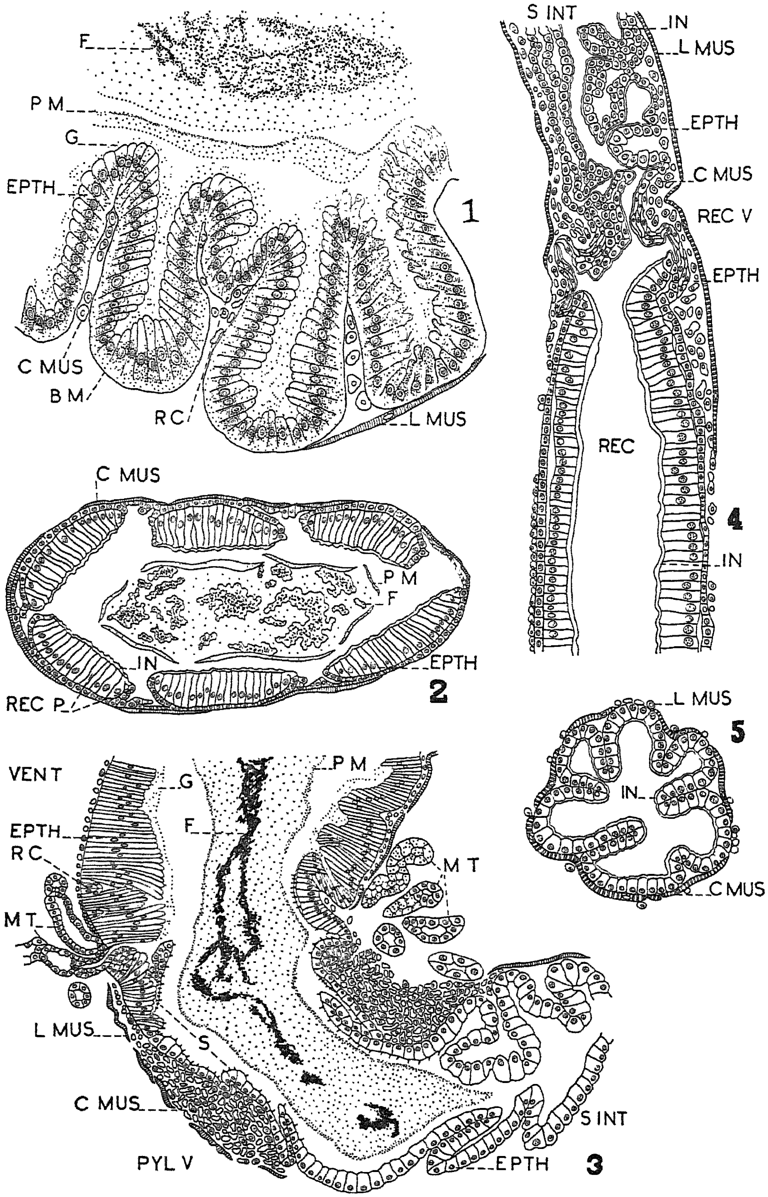

P
C MUS
EPTH
IN
LUM
4
L MUS


M T
EPTH
L MUS
C MUS
G
EPTH
P M
F
5


LUM
EPTH
B M
2


B M
EPTH
LUM
6


OES
CROP
PVENT
OES V
1
VENT
MT
S INT
REC
REC P
CROP
S
IN
PVENT
C MUS
L MUS
IN
EPTH
2
L MUS
EPTH
OES V
VENT
EPTH
OES V
IN
EPTH
PM
3
G
EPTH
L MUS
C MUS
P


F
P M
G
EPTH
1
C MUS
B M
R C
L MUS
C MUS
P M
F
IN
EPTH
REC P
2
S INT
IN
L MUS
EPTH
C MUS
REC V
EPTH
REC
4
IN
L MUS
5
IN
C MUS
VENT
G
P M
EPTH
F
R C
M T
M T
L MUS
S
C MUS
S INT
PYL V
EPTH
3

QUANTITATIVE DETERMINATION OF RHYTHMICITY IN ORGANISMS

ORLANDO PARK,
Northwestern University

Within recent years increasing attention has been paid to the analysis of periodic activity of animals under controlled conditions by ecologists, and to periodic rhythms within the organism by physiologists. This general subject has been recently discussed (1), but there are several aspects of general organismal activity which need additional emphasis.

It is quite clear that there are several categories of activity; second, that this activity pattern of a species is complex and specific; third, that the activity pattern can be modified by the environment. The last two generalizations are obvious, but the first should be examined. Periodic environments are in general inhabited by species having periodic activity patterns, while certain social species and those species living in relatively constant environments tend to have an arhythmic activity pattern. The various permutations of organismal activity may be arranged within the following outline of diel patterns:

I. RHYTHMIC ACTIVITY (Periodic Activity).
   An activity pattern in which the fundamental characteristics of the activity-inactivity curve for a species population recur through successive day-nights (diel periods).

   1. *Environmental Type* (Exogenous Type).
      Periodic activity in which the pattern is directly induced by, and controlled by, the periodic environmental factors.
   2. *Endogenous Type.*
      Periodic activity in which the pattern is resident in the protoplasm, therefore more deeply-seated, and not directly induced by, but may be modified by, the environment.
      a. *Habitual Activity.*
         Endogenous activity which is the result of past experience, or induction in the individual, and consequently indirectly induced by the environment.
      b. *Inherent Activity* (Instinctive Activity ?).
         Endogenous activity which is a part of the species heredity.
   3. *Composite Type.*
      Periodic activity in which the pattern is in part exogenous, and in part endogenous.

II. ARHYTHMIC ACTIVITY (Aperiodic Activity).

Activity of a species population, the individuals of which do not exhibit an average periodic pattern, but in which each individual exhibits a varying activity through successive day-nights.

The experimental findings for these several categories have been sorted in the discussion alluded to. Obviously such an outline is an expedient scheme, as well as a logical one. It is designed for laboratory analysis, since the proper placing of a pattern cannot be definitely made on uncontrolled data. For example, the overwhelming majority of animals has a periodic activity, but whether a particular individual has its pattern induced and controlled by the environment, or has an endogenous pattern, can be discovered only by placing the animal in a constant environment. Under constant conditions, if the pattern persists the activity may be habitual or inherent, and these two types can be separated with certainty only by breeding the species under constant conditions. It is also obvious that objective recording apparatus must be employed, preferably electrical apparatus, utilizing either a continuous record, or if a drum is used then its diameter and speed adjusted so that activity peaks will not obscure each other. Complete control is desirable, as well as non-disturbance of the animal through the changing of records, replenishing food and water supplies, noise, *et cetera*. The possibility of indirect tutelage and learning or induction of various kinds, as well as the operation of little known physical influences should be realized, and where possible guarded against. I am inclined to suggest that nothing more than a bare start has been made in the method of attack on the problem, or in the accumulation of critical information.

To implement the assignment of activity pattern, the following mathematical suggestion is made:

Let: A. *Amplitude* of a twenty-four hour (diel) cycle.
F. *Frequency* of a twenty-four hour (diel) cycle.
A. I. *Activity Index*.
T. A given twenty-four hour trial.
K. Trials run under constant environmental conditions.
R. Trials run under the normal fluctuating environmental conditions.
a. *Actant*. An actant is the percentage for any given hour of the total activity for that diel cycle, the total activity for the cycle equaling 100%.

d. *Diant.* A diurnal actant.
n. *Noctant.* A nocturnal actant.
v. *Vocant.* An actant which is measured by vocalization, stridulation or other sound production, rather than by movements of the animal.
p. *Populant.* The average actant of a population.
N. Average of the noctant gain over 50% activity for a diel cycle.
D. Average of the diant gain over 50% activity for a diel cycle.
0^n Number of trials out of a given experiment (ten trials suggested) which show a nocturnal gain.
0^d Number of trials out of a given experiment (ten trials suggested) which show a diurnal gain.

The following figure (Fig. 1) gives graphical expression to some of these terms which have been suggested to (1) facilitate the formulation of a mathematical approach to the study of diel periodicity, and (2) bring order to a rapidly expanding research field. A tentative formulation follows:

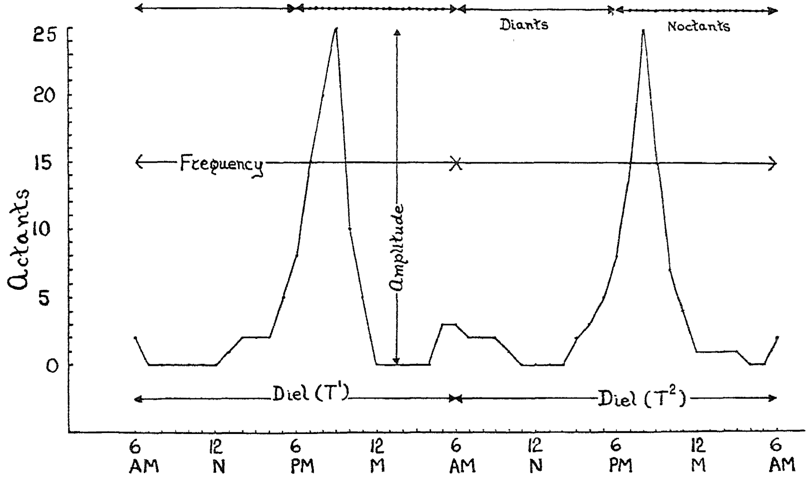


Fig. 1. Structure of a Typical Activity-inactivity Curve, Over Two Diel Periods, for a Hypothetical Nocturnal Animal.

$$\frac{N\,0^n}{D\,0^d} = A.\,I.\left(\text{at } T^{10}\ (R \text{ or } K)\right)$$

I. Where individual activity is being measured by recorders in the field, or under normal fluctuating environmental factors, the application of this formula to the activity units collected will serve to separate those animals having a periodic activity from those having arhythmic activity. Where population activity is being studied special criteria will be employed which, when stated as populants, can be directly compared with recorded activity.

II. Where activity is being studied in the laboratory under "constant" conditions, the same formula will serve to (1) separate arhythmic from endogenous activity, where the latter is synchronized with the diel cycle, e. g., on a twenty-four hour frequency; (2) estimate quantitatively the degree of nocturnal or diurnal endogenosity of such synchronized activity; (3) measure loss of amplitude in successive diels if the actants are analyzed in successive samples where synchronized periodic activity is involved.

III. To separate habitual from inherent endogenosity, the animals must be bred in the constant experimental conditions, shielding the new generation from contact or tutelage of parent or parents, and application of the formula. Under these conditions, periodic activity in the generation thus born will be inherent activity in the strict sense. This is difficult to accomplish but oviparous invertebrates would appear to be the best research material for such an attack.

This formula will not anlayze unsynchronized activity rhythms, e. g., 25 hour periodism, *et cetera*, since in such a species, the cycle would shift through time on successive diels. Under such conditions, the first sample might show an endogenous diurnality, but a larger sample, involving fifty trials, might show an arhythmic activity index although the rhythm would be intact. This would be a consequence of the shift in noctant-diant ratio.

In addition to rhythms not on a twenty-four hour frequency, there is also the possibility of rhythm with a varying frequency. In both such possibilities a much more complex formulation will have to be applied.

For activity patterns synchronized on the diel rhythm, the simple formula will analyze the activity curve on a quantitative basis in terms of actants but to employ the formula, night and day must be definitely limited since the length of day and night varies regularly with latitude and time of year. There are numerous ways in which day and night can be arbitrarily fixed, depending upon the type of investigation being pursued. For example, nocturnal activity may be said to be the activity (1) between sunset and sunrise, either on an astronomical basis or on an arbitrary photometric standard of so many foot-candles, at a given latitude and time of year, in which case this designation of nocturnal may have to be factored, or (2) average sunset to average sunrise at a specific latitude and time of year, or (3) for experimental purposes some arbitrary designation, as from 6:00 P. M. to 6:00 A. M., *et cetera*. Similarly diurnal activity would then be the converse of any one form of designation adopted for nocturnal activity.

In the second place, ten complete diel periods are given in the above formula, merely as a suggestion. Ten trials may be sufficient, or a thousand trials may be necessary. Experience in frequent sampling of the data will demonstrate how many trials are needed to give an accurate activity index of a species activity pattern.

The terms N and D of the formula must be understood. If ten diels are used, the actants for each diel are determined and then, using the standard day and night decided upon, the actants are separated into diants and noctants respectively. Obviously, in an arhythmic species the diants and noctants tend to equal each other, in a nocturnal species the noctants are many and diants few, in a diurnal species the diants are many and the noctants few. N, the average gain in nocturnality, is the average of the noctants of the ten trials over 50% activity. Thus a species with a theroetical 100% nocturnality, would have a net average of 50%, while an animal with 80% nocturnality, would have a net average of 20%, etc. D is formed in the same way as N, using the diants instead of noctants.

It is necessary to express our activity data in some such way as per cent. This is due to increasing investigation on different kinds of animals, using many different kinds of recorders. Thus data are available in the form of vocalization-rate, distance moved per time unit, number of movements per time unit, various activity units, and so on, so that only a percentage figure, like the actant or its variants, is suitable for direct comparison. To further clarify the method, several hypothetical examples are given:

Example 1. Animal exhibiting 100% nocturnal endogenosity.
10 diels with 50% noctant gain each (maximum):

$$\frac{50 \times 10}{0 \times 0} = \text{A. I. } \infty$$

Mathematically, this is the upper limit of the activity index, and to my knowledge has not yet been demonstrated for any species, although many species have a high A. I.

EXAMPLE 2. Animal exhibiting no periodicity, e. g. arhythmic. 10 diels with 5 of them having a 50% noctant gain, and 5 of them having a 50% diant gain, or some similar combination in which no net gain could be demonstrated for the experiment.

$$\frac{5 \times 50}{5 \times 50} = \text{A. I. of } 1.$$

Where the A. I. approaches unity, arhythmicity is demonstrated. All arhythmic species under constant conditions show such a low activity index.

EXAMPLE 3. Animal exhibiting 100% diurnal endogenosity. 10 diels with 50% diant gain each (maximum) :

$$\frac{0 \times 0}{50 \times 10} = \text{A. I. of } 0$$

Mathematically, this is the lower limit of the activity index, the latter having a spread from ∞ to 0, with perfect arhythmicity at the median point.

Once the absence of periodicity, or its presence is known, then by shift from constant conditions to conditions involving one varying influence at a time, the degree of exogenosity and endogenosity may be determined, etc.

The following table (Table I) gives several A. I. which have been determined experimentally within recent years:

TABLE I

EXAMPLE OF ACTIVITY INDEX

ANIMAL	CATEGORY OF ADULT	A. I.	CALCULATED FROM
Cambarus pellucidus..........	Arhythmic............	3.4	(2)
Tamais striatus griseus........	Endogenous diurnal.....	0.0102	(3)
Spirobolus marginatus.........	Endogenous nocturnal..	960.0	(4)

From this table we see three activity indices, well spread out over the range of the scale. The chipmunk A. I. is for the first ten trials only, since the rhythm tends to shift rapidly under constant conditions of darkness, temperature and humidity. This may indicate a high degree of habitual endogenosity in this species, but the work on the animal has just begun. The cave crayfish A. I. is based on ample data, and the A. I. for the milliped is within the expected range for the species.

SUMMARY

A discussion of the quantitative estimation of organismal activity is given, and certain mathematical suggestions are made to implement the quantitative study of rhythmicity.

LITERATURE CITED

(1) **Park, Orlando.** 1940. Nocturnalism—the development of a problem. Ecol. Mono., 10: 485–536.

(2) **Park, Orlando, Roberts, T. W., and Harris, S. J.** 1941. Studies on nocturnal ecology, VIII. Preliminary analysis of activity of the cave crayfish, *Cambarus pellucidus*. Am. Nat. (In press.)

(3) **Park, Orlando and Woods, L. P.** 1940. A modified Hemmingsen-Krarup mammalian activity recorder. Proc. Soc. Exp. Biol. Med., 43: 366–370.

(4) **Park, Orlando.** 1935. Studies in nocturnal ecology, III. Recording apparatus and further analysis of rhythm. Ecology, 16: 152–163.

Entomophagous Insects

Occasionally a biologist finds a book in his field of major interest which proves to be exactly what he needs in graduate teaching and research. This has been this reviewer's reaction to Mr. Clausen's new book on Entomophagous Insects.

The book is a remarkable one volume compilation of the greatly scattered knowledge and detailed information on entomophagous insects found in the world literature. In addition to the compiled information the author has introduced a great amount of original data derived from his wide experience with parasitoid species. The book does not follow the usual presentation of information in chapters but treats the subject matter from the viewpoint of insect orders and families. This arrangement is highly desirable for an investigator or teacher.

The author emphasizes the importance of parasitoid species over predacious forms by the amount of space allotted to the respective groups. Briefly stated the Hymenoptera (almost exclusively parasitoid families) covers 342 pages and the Diptera (largely parasitoid information) 140 pages. A fascinating compilation of the known information about Strepsiptera covers 25 pages. The remaining 100 pages includes the information on the following orders, chiefly predacious: Lepidoptera, Coleoptera, Hemiptera, Thysanoptera, Trichoptera, Mecoptera, Plecoptera, Neuroptera, Odonata, Corrodentia, Orthoptera, Dermaptera, and Thysanura.

Throughout the discussion of the parasitoid groups the author summarizes the significant facts about several species in each family. He also has incorporated many excellent drawings of immature stages stressing their detailed morphological characteristics and habits. At the end of the book over 1000 references to the world literature on entomophagous insects may be found.

Mr. Causen is to be congratulated on his splendid presentation of the existing knowledge on entomophagous insects, particularly parasitoid species. Biological control entomologists may now possess an authoritative and useful storeroom of facts on entomophagous insects.—*Alvah Peterson.*

Entomophagous Insects, by C. P. Clausen. x+688 pp.; 257 figures, Biblio. New York, McGraw-Hill Book Co., Inc. 1940. $7.00.

PRESENCE OF THE LIGAMENTUM BOTALLI IN THE GOLDEN EAGLE AQUILA CHRYSAËTOS (L.), THE RED-TAILED HAWK BUTEO BOREALIS BOREALIS (GMELIN), AND THE COMMON PIGEON COLUMBA LIVIA (L.)

FRED H. GLENNY,
Department of Biology,
University of Akron

INTRODUCTION

During the preparation of a series of studies on the main arteries in the region of the heart of birds (3), the writer had the opportunity to observe a ligament to which no direct reference had been made in the better known references on avian morphology.

As the writer has already noted in other discussions on avian morphology (2 and 3), little work of a serious nature has been undertaken in the study of bird arteries since the close of the 19th century.

Recently, during a study of the arteries of the Golden Eagle (*Aquila chrysaëtos*), the Red-tailed Hawk (*Buteo borealis borealis*), and the common pigeon (*Columba livia*), it was the writer's good fortune to observe a peculiar ligamentous structure lying along the ventral surface of the right 4th aortic arch. Careful removal of the fascia which surrounded the aortic arch revealed this structure to be a separate ligament and not part of the aortic arch.

OBSERVATIONS

An unrecognized ligament was found to be attached to the aortic arch just anterior to the junction of the ligamentous left 4th aortic arch and the dorsal aorta in each of the three species studied. The ligament passed anteriorly along the ventral surface of the right 4th aortic arch until it reached a point near the right pulmonary artery—just posterior to the bend of the right 4th aortic arch and the subclavian artery. The ligament formed an anterior attachment with the pulmonary artery just before it entered the lung.

A ligamentous vestige of the left 4th aortic arch was located in the normal position in each of the three species of birds.

The ligament of *Aquila* possessed a minute lumen from which a small amount of blood was obtained. It appeared to have served as a functional blood vessel during the late embryonic stages in this species. In contrast to this condition, the ligament of both *Columba* and *Buteo* entirely lacked any evidence of a lumen and no blood could be obtained.

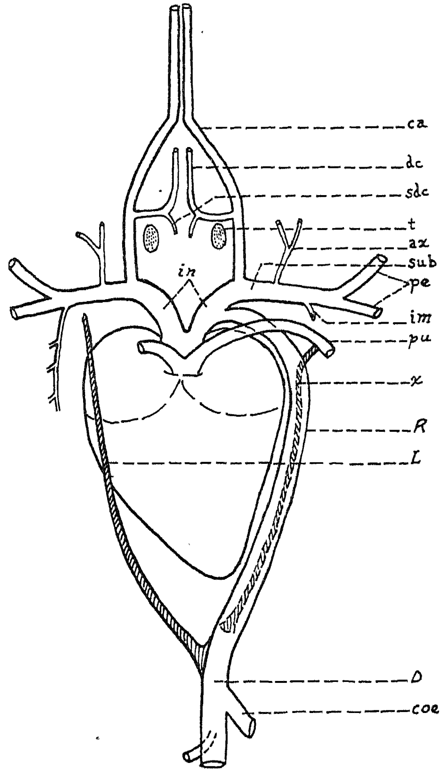


Diagram of the main arteries in the region of the heart of *Columba livia*. Dorsal view.

ax, Axillary artery; ca, internal carotid artery; coe, coeliac artery; dc, external carotid artery; im, internal mammary artery; L, ligamentous vestige of the 4th left aortic arch; D, Dorsal aorta; pe, pectoral artery; pu, Pulmonary artery; R, 4th right aortic arch; sdc, superficial branch of the external carotid artery; sub, Subclavian artery; t, Thyroid gland; x, Ligamentum Botalli; in, Innominate artery.

DISCUSSION

All of the commoner references to the 6th aortic arches of birds indicated that the primitive or embryonic connections with the dorsal aorta were completely atrophied during the late embryonic development of the bird,[1] and especially after the connections with the lungs had been established.[2] This is not entirely the case, as has been shown in the above evidence.

Since the posterior end of the ligament was inserted in the dorsal aorta at about the position expected in the embryo, and since the anterior attachment was made with the pulmonary artery, it was finally concluded that this ligament was a vestige of the embryonic 6th aortic arch. Once this had been established, it was a simple matter to recognize the ligament as a vestige of the *ductus arteriosus* or *ductus Botalli* (5 and 6). The *ductus Botalli* is reported in the Urodeles and the embryonic stages of the amniota. Among the higher vertebrates, including mammals, a ligamentous vestige of the ductus arteriosus has been reported (4 and 5).

The writer could find no reference to the occurrence of this ligament in birds. From the above evidence, however, its occurrence and persistence in certain species of birds has been established.

It is the writer's opinion that this ligament should be referred to as the *Ligamentum Botalli* since it has its origin in the *ductus arteriosus* or *ductus Botalli.*

CONCLUSIONS

It may be concluded, from the above evidence, that this ligament is a persistent vestige of the embryonic 6th aortic arch. Furthermore, it may be concluded that, although this structure is reported from but three species of birds at the present time, the vestigeal portion of the 6th aortic arch may be found in still other species of birds, and may be anticipated in still other species of Raptores.

It is the writer's opinion that the persistence of this ligament represents a primitive avian condition, and helps to bear out the writer's contention in a previous paper (3) that the arrangements of the arteries in the region of the heart may later be used to show certain fundamental natural relationships among the various families of birds.

---

[1] "Der dorsale Abschnitt des 6. Bogens (des Pulmonalis bogens) fällt beiderseits völligem Schwund anheim, nachden er kurze Zeit während des Embryonallebens als Ductus Botalli die Lungen arterie mit der dorsalen Aorta verbunden hat." (6).

[2] "With the development of lungs a pair of pulmonary arteries are developed from the 6th pair of arches on the ventral side of the pharynx. These grow back into the lungs, while the rest of the arch, dorsal to their origin, becomes reduced to a small vessel, the *Ductus arteriosus* (d. Botallii) in some Urodeles, and persists occasionally vestigially in higher vertebrates. Elsewhere it entirely disappears." (5).

SUMMARY

1. The *Ligamentum botalli* was observed in *Aquila chrysaëtos*, *Buteo borealis borealis*, and *Columba livia*.
2. The *Ligamentum Botalli* represents the vestigal portion of the embryonic 6th aortic arch which forms the attachment to the radix aorta.
3. The ligament was attached posteriorly to the radix aorta and anteriorly to the pulmonary artery.
4. Fundamental natural relationships may be established by the presence of such vestigeal structures in the various species of birds, at least within the various orders and families of birds.

REFERENCES

(1) **Beddard, Frank E.** 1898. *The Structure and Classification of Birds.* London, Longmans, Green & Co.

(2) **Glenny, Fred H.** 1939. *An Anomalous Artery in the Kingfisher* (*Ceryle alcyon*). The Ohio Journal of Science, 39: 94–96.

(3) ———. 1940. *A Systematic Study of the Main Arteries in the Region of the Heart—Aves—Part I.* The Anatomical Record, 76: 371–380.

(4) **Heilmann, Gerhard.** 1927. *The Origin of Birds.* New York, D. Appleton and Company.

(5) **Kingsley, J. S.** 1926. *Outlines of Comparative Anatomy of Vertebrates.* Philadelphia, P. Blakiston's Son & Co.

(6) **Stresemann, E.** 1927–32. Aves—*Handbuch der Zoologie*, 73: 206.

Laboratory Directions

It is an almost impossible task for one person to evaluate fairly a laboratory manual in general biology. It is unusual to find two teachers who agree on the content of such a manual, to say nothing of the arrangement and mode of presenting the material.

The manual before us is a loose-leaf assembly divided into three sections: I. Botany, II. Invertebrate Zoology, III. Vertebrate Zoology. The emphasis of the writers is apparently upon morphology. There are two preliminary exercises designed to familiarize the student with the microscope and its use.

Part I. encompasses the Plant Kingdom with twelve exercises covering Thallophyta (8 exercises), Bryophyta (2 exercises), Pterydophyta, and Spermaphyta. The "type-form" is used in the study of each group. Part II. contains fifteen exercises, three of which are devoted to Protozoa, the remainder to Porifera, Coelenterata, mitosis, Platyhelminthes (3 exercises), Nemathelminthes, Annelida, Mollusca, Arthropoda and Echinodermata. Part III. includes eighten exercises, some of which cover as much as eleven pages. The Protochordates are allotted three exercises, the remaining fifteen, one each to Petromyzon, Squalus, Perch, fish scales, caudal fins, Necturus, frog, turtle, lizard, Pigeon, fetal pig, heart kidney, eye, brain and cranial nerves.

Careful dissection by the student and much drawing are essential in using this guide. Such a manual presumably would be suitable for a course in Comparative Anatomy although it is not in accord with the modern conception of a "generalized" course in Biology.—*Paul E. Schaefer.*

Laboratory Manual of General Biology, by John G. Arnold, Jr., and Timothy L. Duggan. Fourth Edition, 275 pages. St. Louis. C. V. Mosby Company, 1940.

BOOK NOTICES

A Short Course in Zoology

What shall be the content of a one-semester course in Zoology? Probably no two teachers would include the same material. Certain type animals and a group of general principles would be common to both but each individual would emphasize certain features which the other had minimized or omitted. These facts make the selection of materials for such a course especially difficult.

Dr. Potter of Texas A. & M. presents his concept of what a one-semester course should include but has so organized his material that other teachers may rearrange the order or omit whole chapters if it is so desired.

The bullfrog and the rat are discussed in some detail as representatives of the vertebrates. Euglena, Amoeba and Paramecium were chosen as types of Protozoa. Hydra, Planaria, Ascaris, Earthworm, Starfish, Freshwater Mussel, Crayfish and Locust typify the invertebrates. Several general chapters such as Protoplasm and the Cell, Metazoan Organization, Chordates in General, Physiology, Endocrine Glands and their Functions, Sexual Reproduction and Development of the Individual, Genetics and Eugenics, and several others greatly broaden the scope of the book.

The importance of ecology is recognized by the inclusion of three specific chapters, Animal Parasitism, The Animal and its Environment, Animal Distribution. These chapters are well done save for the tendency, common to ecologists, to obscure meaning by the use of technical terms unnecessary to the general student.

The closing chapter, "The Theory of Evolution," panorams the topic, but lists a few more extensive references at its close as is the practice with each preceding chapter.

An attempt to pack the utmost into such restricted space makes condensation and generalization essential, which in turn permits inadvertent inaccuracy, exemplified by the discussion of metabolism and growth on page 43. The text is copiously illustrated. Any one interested in a one-semester text will do well to examine this book.—*Paul E. Schaefer.*

Essentials of Zoology, by George Edwin Potter. 526 pages. St. Louis, C. V. Mosby Co., 1940. $3.75.

Plant Microtechnique

This contribution will fulfill the needs of most technicians dealing with plant tissues. Although extensive, it is not encyclopedic and is easily read. Many of the more important microtechnical methods are reviewed and in addition numerous previously unpublished methods are included. Chapters with critical evaluations are found dealing with the more familiar problems of killing and fixation, dehydration, embedding, sectioning and staining. Other chapters present material on whole mounts, glycerine, celloidin, paraffin, cytological, smear, and microchemical methods. The chapter on smear methods is timely, up to date, and much more extensive than is contained in any other text known to the writer. The chapter on celloidin is quite brief. The part on microchemical methods should be of considerable aid to histologists. However, many of the tests are not given with much detail. Some microchemists will not agree that thick sections (up to 50 microns) are more satisfactory to work with than thin sections. A short chapter on sources of materials will be of value to many students.

Over half the volume is devoted to chapters on the various plant phyla. Much valuable information is given on the time and where to collect, culturing, and preservation of specimens.

The book is illustrated with a frontispiece and 110 text figures. Most of these are photomicrographs. The bibliography consists of 256 references. An adequate index is included. In the writer's opinion, this is the best book so far produced on the subject of plant microtechnique.—*Glenn W. Blaydes.*

Plant Microtechnique, by Donald Alexander Johansen. xi+523 pp. New York, McGraw-Hill Book Company, Inc. 1940. $4.50.

THE OHIO JOURNAL OF SCIENCE

VOL. XLI MARCH, 1941 No. 2

THE GENERIC AND SPECIFIC STATUS OF FOUR OHIO SPIDERS OF THE GENUS AGELENOPSIS

PAUL J. SEYLER,
Ohio State University

INTRODUCTION

Every taxonomist sooner or later faces a situation in which he must determine whether he is dealing with a single highly variable species, or with several species which appears to intergrade. This problem confronting us has been recognized by Petrunkevitch, Emerton, Comstock, Chamberlin, Ivie, Gertsch and others.

Arachnologists have been perplexed by the variability of a species which has been considered *Agelena naevia* Walckenaer as the following quotations will indicate.

Petrunkevitch (1925) on page 561 states: "It does not require prolonged study to show that variation in size in *Agelena naevia* is very great. Specimens collected in the same locality, often under the same piece of loose bark, guarding their cocoons with eggs, and therefore in the same stage of maturity, are occasionally twice the size of others. The fact that two such distinguished arachnologists as Graf Keyserling and Becker have described two new species of Agelena from North America, which long since have been recognized as synonyms of *A. naevia*, shows that the variation in structure is also sufficient to be considered as specific in absence of intergradient forms."

Emerton (1890) recognized the great variation that exists in both the palpus of the male and epigynum of the female. He has illustrated four types of palps and seven variations in the atrial opening of the epigynum. He says that, "The shape of the external opening of the epigynum is even more variable than that of the palpal organ."

Comstock (1912), page 586, in his spider book: "This species is either a variable one in the form of the palpi of the males and in the form of the epigynum of the female or more than one species have been confused under this name."

Chamberlin and Ivie recognize several species of this complex, four of which occur in the state of Ohio, namely: *Agelena naevia* Walckenaer, *Agelena americana* Keyserling, *Agelena utahana* Chamberlin and Ivie, and *Agelenopsis emertoni* Chamberlin and Ivie. These men (Chamberlin and Ivie) (1935) suggest that: "This species, with a number of others, has been consistently synonymised with *Agelena naevia* Walck. by later authors." They here were referring to another form (*Agelena potteri* Blackwell) which is referred to later in this paper.

PURPOSE OF PAPER AND ACKNOWLEDGMENT

This paper is an attempt to determine, from a detailed study of the epigyna and palps of a large number of specimens, the true status of the four forms of this genus found in Ohio.

This research was conducted in the Department of Zoology, The Ohio State University. The author wishes to acknowledge his indebtedness to Dr. W. M. Barrows, of the Department of Zoology and Entomology, for the advice and criticism given during the course of this study.

MATERIALS AND METHODS

Material for this problem was collected during the summers of 1937 and 1938. Most of the material was preserved in 95% alcohol. A few specimens were killed, in the field, in Petrunkevitch's fixing fluid. The fluid used was his second formula which keeps indefinitely and which can be used an unlimited length of time without harmful effects to the tissue. It does keep the tissue soft and in good condition. The formula, as Petrunkevitch (1933) gives it, is:

60% alcohol	100 cc.
Nitric Acid, c. p., sp. gr. 1.42	3 cc.
Ether	5 cc.
Cupric nitrate, c. p., crystals	2 grams.
Paranitrophenol, c. p., crystals	5 grams.

In the laboratory, the specimens were first separated as to sex. All of the specimens used were mature and therefore the males with their well developed palpal copulatory organs were easily distinguished from the females, which possess the epigynum.

All males were further separated into four groups on the basis of differences in appearance of several structures of the mature palp. For further study the right palp of ten specimens of each group was taken from the spider and preserved in cedar wood oil. It was found that cedar wood oil; firstly, cleared the specimen to a great degree thus giving greater definition to its parts, secondly, its viscosity being greater than alcohol it aided in suspending the specimen at almost any angle desired for observation and thirdly, the specimens could be observed for long periods of time when using strong light without evaporation or movement due to evaporation currents.

The epigyna of the females, also, were observed to be of four types. From a large number of specimens, twenty-five of each type were selected without regard to size of the spider. The epigyna of these twenty-five females of each group were lifted from the venter of the abdomen, after breaking the chitin covering the copulatory sacs, with dissecting needles. They then were cleaned of excess fatty tissue and placed in individual vials, with the spider from which they were taken, for future study.

Some of the specimens of each type, which had been killed in Petrunkevitch's fixing fluid, were used for more detailed study. The epigyna of these were taken from the specimens in the same manner as the others, then washed in 70% alcohol and prepared for sectioning. The technique followed in the preparation of this material was worked out by Wynkoop (1939). He used diaphanol as a softener of the chitin rather than potassium hydroxide. This latter substance proved harmful to the minute tubules as well as to the softer parts of the epigynum. Diaphanol removes those substances in chitin which usually prohibits sectioning. In his technique, Wynkoop suggested subjecting the material to diaphanol from 70% alcohol. The time required for diaphanol to remove the undesired materials from the chitin depended on the density of the chitin. The smaller and softer epigyna required twenty-four hours while the larger and older specimens required as long as four days to turn milky white, which is the indication that the softening process is completed. When the material was ready for sectioning it was taken from the diaphanol and washed thoroughly in 70% alcohol, dehydrated and embedded, following the usual procedure of paraffin sectioning. The sections were cut eight microns in thickness. They were mounted serially and stained with aneline blue on the slides. It was found that an overstaining of the sections brought out the minute orifices and slight differences apparent in the chitin of the various structures. Camera lucida drawings were made of these serials, then in some instances the drawings were mounted on cardboard. These sectional drawings which were mounted on cardboard made exact models of the epigynum when cut out and put together, for detailed study.

RESULTS

Upon examination of the specimens in the collection it was found that both males and females could be separated into four distinct groups on characters presented by the mature palp of the males, and, by the epigynum of the females.

DESCRIPTION OF THE MALE PALPS

The palp contains the copulatory apparatus on the ventral surface of the terminal segment. Only the cymbium can be seen in a dorsal view. It usually is covered with the same thin chitin, yellowish in color, as the other segments of the pedipalps. The basal portion of the cymbium is hemispherical but the distal end is comparatively long and narrowly tapered. The entire surface of the cymbium is sparsely covered with short hairs and contains from three to six spines, irregularly placed. This structure is similar in all the four groups. From the ventral view the main parts of the copulatory apparatus can be observed. Hidden from view, in a specimen which has not been especially dissected or treated, are various structures embedded in an excavation in the base of the cymbium. These structures are common to all types and therefore are not of importance in this study.

The two structures which differ in each group are the conductor (Pl. III, a) and the tip of the embolus (Pl. III, b). The embolus is a long, evenly coiled tube of one and a quarter to one and a half turns in length which usually does not extend much beyond the boundary of the cymbium. It has its origin near the center of the enlarged part of the cymbium. The swing of the coil is from the point of origin first ectal, then posterior, medial and anterior. The tip lies either in this anterior sector, or the posterior of the second loop, depending upon the length of the embolus and the tightness of its coil. The last quarter of its length shows that the embolus is a tube formed by a roll of the chitin with the outer edge overlapping as much as half the circumference of the tube thus formed. In some forms the roll is not complete at the tip, resulting in a trough instead of a tube.

The conductor is a hard and black chitinous projection, pointing forward and situated on the ectal side of the palp. It has its origin at the same level as, and ectal to, the origin of the embolus. Its length and shape varies in the different forms. The chitin is usually rough and, especially in the older specimens, is broken or splintered along the edges.

In comparing the differences in these two structures of the palp of these four groups; the length, thickness, and the end portion of the embolus, and the shape and size of the conductor are significant. The specific name of the spider possessing the type of palp being described will be used to distinguish it.

The longest, most uniform embolus is to be found in *naevia* (Pl. III, *naevia*, b). The hard portion of the chitin is shiny black with a series of fine ridges running the length of the coil. The portion of the roll which overlaps is of thin, almost transparent chitin. This overlap is toward the inside of the coil of the embolus. The coil of the embolus completes a full one and one half turns with the tip lying near the center of the circle formed by the complete revolution. Near the end the embolus tapers considerably and also bends back (dorsally) slightly toward the main body of the palp. The tip is plain, without a notch or protuberance and the roll remains wound to the tip. The conductor is very regular in this form (Pl. III, *naevia*, a). It is comparatively long and narrow with longitudinal ridges extending its entire length. The conductor is concave in cross-section with the cavity facing the palp. The anterior end is pointed, the point being formed by the ventral edge being longer than the dorsal.

The coil and appearance of the embolus of *emertoni* (Pl. III, *emertoni*, b) are essentially the same as in the preceding form. But the tip of the embolus is very distinctive for this type. The overlapping edge of the chitin breaks away from the roll in the last quarter turn and forms a gutter which widens toward the tip, with the tube portion forming its inside margin. At the tip the tight complete roll can be seen partially encompassed in the loose flap. The tip edge contains a heavy, black knob of chitin which gives it a forked appearance under low magnification. The conductor (Pl. III, *emertoni,* a) is very similar to the same structure of *naevia* except that it is not quite as long and pointed.

In *utahana* the embolus (Pl. III, *utahana,* b) is similar to *naevia* but is not quite as long. It is perfectly plain, except for a slight thickening of the chitin at the end, and continues the regular swing of the coil. The roll remains closed as a tube throughout the entire length of the embolus. The conductor (Pl. III, *utahana,* a) of this type is distinctive. It is very wide at the base, and has very little transverse curvature, when compared with the two forms already described. The anterior end is blunt with a thick chitinous knob at the outside, anterior edge.

These two diagnostic structures of the form *americana* show a great departure from the normal plan expressed in the other forms. Both structures are heavier in construction. The embolus is shorter and the conductor larger in size when compared with the others.

The embolus (Pl. III, *americana,* b) is short, thick and tightly wound. It completes only one revolution with just the tip extending over the origin. The roll of the embolus opens, before the complete revolution is made, into a deep trough, with the concave surface exposed anteriorly. The ventral edge of the trough has a distinct projection the apex of which protrudes forward beyond the regular curvature of the embolus. The distal side of this projection meets the dorsal edge of the trough at the tip.

The large and bulky conductor (Pl. III, *americana,* a) of this form is not hidden by the embolus. In cross-section it is almost a complete circle, with the open portion facing the main body of the palp. On the posterior end of the conductor is a hard black chitinous knob. The anterior edge is rough and the ventral corner possesses a protruding tip.

DESCRIPTION OF THE EPIGYNA

The epigynum, as found in the females of the four forms of this genus, may be divided into three units. It has a single cavity or atrium (Pls. I, II, h) which opens to the outside on the ventral surface. This atrium is common to the two large structures, the copulatory sacs (Pls. I, II, a), which extend anteriorly from each side of it. These two units are independent of each other and contain identical structures. The epigynum is therefore bilaterally symmetrical. Each of these two units is really a single, coiled and much-twisted tube in which appear definite structures differing in size, shape, color and position. The names given to the parts of the epigynum in this paper are the same as those suggested by Petrunkevitch (1925). They are the atrium, vulva, copulatory sac, diverticle, seminal receptacle, connecting tube, fertilization tube and the blind canals of the copulatory sacs and receptacles.

The only portion of the epigynum to be seen in an undissected spider is the atrium (Pls. I, II, h). It is the only external opening of the epigynum and is located on the anterior margin of the epigastric groove on the ventral side of the abdomen. The general shape of the cavity (atrium) is that of an ellipsoid with the long axis parallel to the epigastric groove. The chitin at the external edge of this invagination is heavier and darker than that of the surrounding exoskeleton, forming a ridge, hereafter called the vulva (Pls. I, II, g). The posterior edge of this chitinous ridge is the thickest and contains a depression in its vertical surface which faces the epigastric groove, in some species quite prominent and in others almost lacking. This depression (Pls. I, II, i) is usually wider inside than at the surface of its lateral extremities which gives it the semblance of a lateral pouch on each side.

The shape of this hard chitinous rim, or vulva, which surrounds the atrium differs for each of the four groups studied. The anterior edge may be without obstructions, that is, it is smooth and without a projection as in *americana* (Pl. I, Fig. 3), or may possess notches or a prominent lip. *Naevia* (Pl. I, Fig. 1, g) presents this other extreme. The anterior edge of this form possesses a pronounced lip in the center which extends over the atrium slightly more than half the short axis of the ellipse. The width of the lip is from one-half to one-third of the total width, or long axis of the atrium. This lip is slightly notched in the center of its margin. The anterior portions of the vulva of the two remaining types (*utahana* and *emertoni*) (Pl. II, Figs. 5, 7, g) are quite similar. Instead of either of the two extremes mentioned, their anterior margins possess two notches equally spaced, one on each side of the median line. The notches of *emertoni* are usually less pronounced. The atria differ in these two species in that *utahana* is wider in proportion to the width than is the other.

The shape of the pouch in the posterior margin of the rim of the vulva in *emertoni*, *naevia* and *americana* (Pls. I, II, Figs. 1, 3, 7, i) is very similar. It varies in specimens of the same group but in all three of these forms this depression takes in better than two-thirds of the posterior margin of the vulva. The epigynum of *utahana* (Pl. II, Fig. 5, i) stands in contrast with the others concerning this pouch in that it is almost as wide in its dorsal-ventral measurement as in its lateral extensions. The concavities at the lateral extremities are not prominent and are sometimes lacking.

The copulatory sacs proceed anteriorly from each side of the common atrium in all these forms. These sacs are of very thin, almost transparent chitin. They may be simple, undivided structures or may give the appearance of having a second lobe in which the anterior portion is bent back on the main stem leading from the atrium. These reverted portions occupy the space between the two lateral or main stems of each side with their extremities dorsal to the seminal receptacles.

The copulatory sacs of *americana* (Pl. I, Figs. 3, 4, a) are of the simple type, that is, they are single sacs arising from the lateral surface of the atrium and do not fold on themselves at the anterior edge. *Utahana* (Pl. II, Figs. 5, 6, a) shows a slight reversion of the sac while the two remaining forms, *naevia* and *emertoni* (Pls. I, II, Figs. 1, 2, 7, 8, a) are long and fluted. In the latter two forms the sacs extend forward from the common atrium and then turn back on themselves with the folded portion toward the middle of the epigynum. Further, although the sacs in all these species are transparent, *naevia* and *emertoni* with *utahana* to a slight degree, appear to be wrinkled or plicated. These plications usually are darker than the sac proper in color.

The sacs end in a diverticle which can be distinguished from the sac proper in that it is heavier and more smooth although it is usually of the same light colored chitin. It is in the form of a wide band or roll in some and in others it is flat and covers most of the ventral surface of the copulatory sac to which it attaches. These diverticles end as blind tubes of small diameter on the dorsal surface between the copulatory sacs. The diverticle of *americana* (Pl. I, Fig. 3, c) is very large, covering most of the ventral surface of the sac and is made of comparatively thick, light colored chitin. In *naevia* (Pl. I, Fig. 1, c) it is tubular and connects with the lower part of the reverted portion of the sac. It then continues as a loop toward the ectal edge of the sac then bends anteriorly and finally ends in the blind tube on the median line of the epigynum with its end dorsal to the other structures and pointing backwards. *Emertoni* (Pl. II, Fig. 7, c) presents the longest diverticle. It is tubular and attaches to the end of the reverted portion of the sac, then extends anteriorly in an arc to the median line of the epigynum and ends as a short blind tube similar to *naevia*. The diverticle of *utahana* (Pl. II, Fig. 5, c) is short and simple. It is less distinguishable from the sac than in the other forms and tapers quickly as it extends dorsally along the medial edge, forming the blind tube.

On the ventral surface of each of the copulatory sacs lies a seminal receptacle. These two receptacles are located just anterior to the atrium. In some specimens the receptacles are so close together that their chitinous walls appear to be fused and in others they are quite separate. The cavities of the receptacles which have their walls fused are never connected.

There is so much variation in the shape and position of the receptacles in specimens of a single group that a description of them as found in a single specimen of any one group would not give a true picture (Pls. I, II, Figs. 1, 2, 3, 4, 5, 6, 7, 8, e). In general, it may be stated that in all forms studied the receptacles are easily recognized as the bodies composed of dark and very thick chitin which rest on the ventral surface of the copulatory sacs. Internally they possess a single cavity which may or may not be constricted in the center. Each of these areas, set apart by the constriction, is a continuation of the lumen of the tube which enters the receptacle at that point, one, of the tube connecting the receptacle with the diverticle and the other of the fertilization tube.

Each seminal receptacle is connected to the diverticle of the copulatory sac on which it rests by a single tube. In some this tube is long and narrow and composed of the same hard dark chitin as the receptacle while in others it is so short that the receptacle appears to be connected directly with the copulatory sac. The connecting tubes of *naevia* and *americana* (Pl. I, Figs. 1, 3, d) arise from the medial edge of the copulatory sacs along with, and as a part of the diverticle and enter the receptacles along the dorsal surface, the lumen of the tube entering the cavity of the receptacle at a very sharp angle. In *emertoni* and *utahana* (Pl. II, Figs. 5, 7, d) these tubes arise from the lateral portion of the diverticles and progress across the ventral surface of the copulatory sacs. In *utahana* the tube enters the receptacle in the middle of the anterior surface whereas the tube in *emertoni* enters the receptacle in much the same manner and position as in the first two.

In all these forms there is a very prominent coiled tube (Pls. I, II, Figs. 1, 2, 3, 4, 5, 7, 8, f) leading from the lateral surface of each receptacle and extending almost to the posterior edge of the epigynum. This tube is small and dark in color. In tracing its path, it leaves the lateral edge of the receptacle and swings posteriorly over the ventral surface of the copulatory sac. Continuing posteriorly it then makes one and one-half turns around the neck of the sac and terminates on the dorsal surface of the atrium. The end of the tube (Pls. I, II, Figs. 2, 4, 6, 8, k), which is open, rests midway between the lateral edge and the mid-line of the epigynum. The lumen is small but well defined and extends the entire length of the tube without variation. This tube is called the fertilization tube since it apparently transports the sperm from the receptacle to the uterus which lies just inside the epigastric groove. Since the position of this tube is nearly constant for these four groups no detailed description for each species needs to be given.

The blind tube (Pls. I, II, Figs. 2, 4, 6, 8, j) of the receptacle is short and of the same hard and dark chitin as this body. It arises from the anterior dorsal surface and extends back along the receptacle. In most specimens of all four species the blind tubes of the diverticles end close to the end of these tubes from the receptacles.

DISCUSSION

The genus Agelena was erected, supposedly by Walckenaer, in 1805. But the type form is given in the literature as *A. labyrinthica* (Clerck). Apparently Walckenaer put the genus, to which the species was assigned by Clerck, in synonymy. The form was recognized by others since the following citation is given in Walckenaer's Tableau des Araneides (page 51):

"1. Ag. labirinthe (Ag. labirinthica). Pl. 6, Fig. 55 et 56. Fabr., Linn., Walck., Faun. Paris, t. 2, p. 217, n.° 60. Schaeff., Icon., Pl. 19, Fig. 8. Albin, Pl. 17, Fig. 83. Clerck, p. 79, Pl. 2, tab. 8. Lister, tit. 18, Fig. 18, p. 60.

"2. Ag. marquée (Ag. naevia). Bosc, Manuscript sur les araignées la Caroline, Pl. 1, Fig. 2."

In his description in this work, Walckenaer says that the eyes are eight in number and nearly equal between themselves. The only figure given is of the eye pattern. This shows two strongly recurved rows, the anterior medians of which are much smaller than the rest, they being of equal size. The name of Ag. marquée (*Ag. naevia*) and the reference to Bosc's manuscript are the only mention of this form in this early work.

In the second volume of Walckenaer's Histoire Naturelle des Insectes Aptères he describes the genus Agelena again and gives a very meager description of *naevia*. Although the date on the front page of the book is given as 1837 this work apparently did not appear until July of 1841, according to the footnote on page 473 by White (1841), "July 2. Since this paper was written the 2nd volume of Walckenaer's work has been published." The first published description of *naevia* appears in Walckenaer's second volume. The description is not original with him. He obtained manuscripts from two people who collected spiders in America and then he described the species from their descriptions and figures. In the preface to volume one of the Histoire Naturelle des Insectes Aptères he mentions that Bosc presented him with a manuscript, accompanied by drawings of twenty-five spiders from Carolina. The manuscript was given to him while writing his Tableau des Araneides and only the names of these forms were included. The other manuscript he obtained was written by Thomas Abbot, containing 535 Araneids and Phalangids from Georgia. These drawings were accompanied by a notebook written in English and entitled "Notes and Observations on the Drawings of the Spiders of Georgia." In his description of *naevia*, Walckenaer gives the notes, and not the drawings, of these two manuscripts. The following incomplete description is given by him:

"Abdomen ovale-allongé, fauve, avec deux linges brunes longitudinales, parallèles sur le milièu du bos, et deux bandes brunes sur les côtés, droites dans la femelle, ou qui sont légèrement festoonées dans le mâle. Corselet d'un jaune orange, avec deux bands brunes longitudinales, qui alleignent jusqu'aux yeux. Pattes d'un fauve jaunâtre, annelées de noir aux articulations."

Since the time of Walckenaer, arachnologists have added many species to this genus. It remained for Giebel (1869) to suggest a new genus for the American forms since they differed distinctly from the type form of the genus (*A. labyrinthica*). Many authors state that these new forms have been synonymized with *naevia*, or are variations of that form. The characters given by Walckenaer are of a very general nature and are of the sort which are subject to great variation and overlapping within the four species studied in this paper. Many modern workers with spiders now consider the figure of the palp of the mature male and the epigynum of the female as the most reliable characters necessary to delimit a species. The figures of the palps of *emertoni*, *utahana* and *americana* and the epigyna of *utahana* and *americana* are given with the original descriptions. No figures were given for *naevia* in the first descriptions and where they have occurred in later works they have been called a variety of *naevia*. It is probable, therefore, that the figures given in this study are the first given for this form as a distinct species.

Petrunkevitch (1925) recognized (p. 561) "the great dissimilarity between the external reproductive system of *A. naevia* and that of the closely allied European species, *A. labyrinthica*." The outstanding differences he noted are (p. 568): "The first and most important difference between this species and *A. naevia* is in the position of the organ. Instead of being directed forward, it is directed backward, so that the copulatory pouch and receptacle come to lie between the copulatory opening and the genital groove." Further he noted the "absence of a common atrium and the consequent separation of the reproductive system into two independent units."

The genus Agelenopsis was erected by Giebel (1869) with the type form *A. albipilis*. He set apart this genus from Agelena on the position and size relationship in the eyes. In his new genus he suggests that the eyes are arranged in three rows; two in the first row, four in a straight line in the second and two again in the third row. The anterior laterals are the largest of the eyes. He found them to be different in Agelena. "Auffällig genug von Agelena verschieden, wo die Stirnaugen erheblich kleiner, die zweite Reihe eine Bogenlinie bildet und die hintern Augen weiter aus einander gerückt sind."

Other authors have noted the differences between the American form and the European agelenas. Although he does not recognize the genus Agelenopsis, Simon (1898) describes the eyes of the genus Agelena as being nearly homogeneous, arranged in two sharply recurved rows. The four median eyes form a quadrangle with the sides almost parallel. Also he states, "dans la plupart des cas, les yeux médian antérieurs sont un peu plus gros que les latéraux et que les médians postérieurs." In a text figure, to which he here refers, of the eye pattern of *labyrinthica*, the anterior medians are much larger than the others. He also noted that the patella of the palp in the males of American species was without a point whereas the European forms have an apophysis of one shape or another on the anterior-external surface. In his figure of the patella and tibia of *labyrinthica* he shows a long pointed apophysis on the tibia which extends forward over the tarsus. We do find that the tibia of the palp in the American complex shows a slight rounded projection but it is not as exaggerated as the type shown in his figure.

Cambridge (1897–1905) recognized the genus Agelenopsis although the figures of his Central American forms do not agree in structures of the palp of the males and the epigynum of the females, with the North American forms of this genus. He does say that the spiders of the genus erected by Giebel "differ from Agelena (type *A. labyrinthica*) chiefly in the relative proportion of the anterior eyes, the laterals being much larger than the centrals, whereas in Agelena they are subequal."

Chamberlin and Gertsch (1929) noted that some forms of the genus Agelena had the apical joint of the hind spinnerets shorter than the penultimate and had a prominent, excavated region on the outer side of the tibia of the male palp with two or more conspicuous processes. For these forms Chamberlin erected the sub-genus (Hololena) of Agelena. On the other hand, the members of the genus Agelena (sens. str.) "form a group in which the hind spinnerets have the apical joint much longer than the penultimate, and in which the tibia of the palpus of the male has a single extension on the outer side."

Chamberlin and Ivie (1935) accept the genus Agelenopsis. They describe four new species of this genus in their work. *A. emertoni*, one of the four described by them, is one of the species used in the study of variations of the copulatory apparatus in this paper. The other three forms studied here were originally described as belonging to the genus Agelena. These authors state, however, that the type form (*A. albipilis*) used by Giebel, is a synonym of *A. potteri* Blackwell.

Blackwell (1846) described this species, taken in Canada in the vicinity of Toronto, as belonging to the genus Agelena. It is interesting to note that Blackwell says: "the eyes of the anterior row are larger than those of the posterior row, the intermediate ones being the largest of the eight." This condition is contrary to the findings of Giebel. In observations on the eye pattern of specimens of each group of this series, the author noted that the size relationship of the eyes varies enough so that in some the anterior medians are slightly larger than the laterals of the same row, and in others all four of the anterior row appear to be equal. Since the eyes are mounted on the front and top of the head, with those of the anterior row directed forward and those of the posterior—the medians directed upwards—the laterals to the sides, not all eyes can be seen in full view from any one angle, and their size relationship cannot be easily determined.

The form described by Blackwell (*potteri*) can be accepted as belonging to the genus Agelenopsis, since his description of the palp of the male is in accord with the description of this appendage of the American forms as given by Simon. Blackwell says:

"The cubital and radial joints of the palpi are short; the former is not provided with an apophysis, but the latter has a large, obtuse one at its anterior extremity, on the outer side; the digital joint is oval, but elongated, the extremity being slender and compact; it is convex and hairy externally, concave within, comprising the palpal organs, which are highly developed, complicated in structure with a large, spiral spine, brownish black on the outer and pale yellow on the inner side, which is very prominent and recurved at its extremity, and a strong, dark reddish brown process at the outer side projecting beyond the margin of the digital joint."

The rest of his description is of a general nature, but the description of the end of the embolus of the palp "which is very prominent and recurved at its extremity," and of the conductor "a strong, dark reddish brown process at the outer side projecting beyond the margin of the digital joint," are definitely diagnostic characters for the male of this species. He does not mention the epigynum of the female.

Keyserling (1877) described a new species (*A. americana*) of the genus Agelena from North America, from two specimens given him by Dr. L. Koch. He did not know in what part of the country they were taken since it was not mentioned by the collector. Besides giving a rather complete and detailed description of the color, markings, shape of the body and legs he mentions that the patella of the male palp is short and rounded on top and that the tibia bears a short protuberance which is thick and slightly curved at the tip. This is the typical condition of these segments of the palps of members of this complex.

His description is accompanied by two side views of the palp and one ventral view of the epigynum. He describes the cymbium of the palp as a cover which is somewhat broad and strongly curved and drawn out into a somewhat long, thin beak in front. Also, the embolus which is medium thick becomes thinner and hollow toward the end. He describes the conductor as a flat process, hollow below which is outside the embolus and extends forward. It ends in a small curved tip. According to him the epigynum is a cross-oval pit at the rear part of a low rise. The figures of both the palps and the epigynum given by him are distinct for this form.

Americana has been recognized as a synonym of *A. pennsylvanica* C. Koch by several arachnologists. C. Koch (1843) gives a very meager description of his species and figures a colored dorsal view of the female. He does not mention the epigynum of the female and all characters used are of such a general nature that they could be used for several of the species recognized in this present study. The spelling *pensylvanica*, as it appears in the original description, apparently is a typographical error since it is spelled *pennsylvanica* on his plate. The male of this form was not known to C. Koch. Keyserling gives this comment at the end of his description of *americana:*

"Ob die von C. Koch beschriebene (*Ag. pensylvanica*$_2$) mit meiner identisch ist, von der sie in der Färbung abweicht, lässt sich unmöglich feststellen, da C. Koch nichts über die Gestalt der Epigyne in seiner Beschreibung sagt."

The ($_2$), after the name, refers to a footnote giving the reference to C. Koch's description.

SUMMARY OF THE STATUS OF THE GENUS

The females in this collection fell into four distinct groups on the basis of just one characteristic—the shape of the vulva of the epigynum. The internal structures of these epigyna were distinctly different for each of the four types. One has to note only the shape and position of the copulatory sacs and the diverticles of each type to see that these are characteristic for each species.

A degree of variation in the epigynum was to be noted in the twenty-five specimens of each species. In the first place the epigyna from a group of any one species are not the same size. Such measurements as the total length of the entire epigynum, the length and width of the vulva and the position and shape of the projections on the anterior lip, when present, were made for each group possessing them. The measurements showed that any one character may vary independently of the others. Although some of these measurements revealed considerable variation, none were great enough to cause any uncertainty as to the group in which they belong.

There also was no direct relationship between the size of the epigynum and the length of the spiders from which they were taken. Of the twenty-five specimens of *naevia* measured, the total length from the chelicerae to the spinnerets varied from 18 mm. to 13 mm. The other species showed similar variations in size. There was a tendency for the larger epigyna to be found in the larger specimens but this was not always the case. It may be stated that the variation in the length of the specimen was greater than the variation found in the characters measured in the epigynum, and, that they did not coincide.

The table below gives the extremes for the measurements made in the twenty-five epigyna of each group. The numbers in parentheses represent the length of the spider, or spiders, in which these extremes were found. The measurement given for the length of the vulva equals the short axis of the ellipse while the width equals the long axis, except in *naevia* where the length equals the greatest distance from the anterior to posterior margins of the left side of the protruding lip or tongue, parallel to the length of the spider. The length of the lip in *naevia* is the distance it extends along the short axis. The epigynum of *americana* is without projections on the anterior margin of the vulva. The measurement given for the pouch in the posterior margin of the vulva indicates the width of the external edge of the depression and does not include the lateral pouches. All measurements are in millimeters.

Agelenopsis emertoni. Range of length of the spider, 12 mm. to 8 mm.

	Maximum	Minimum
Width of atrium............	0.60 mm. (12)	0.39 mm. (8)
Length of atrium...........	0.27 mm. (9, 10, 11)	0.18 mm. (8)
Width of pouch.............	0.48 mm. (11, 12)	0.30 mm. (10)
Greatest length of epigynum	1.14 mm. (9, 12)	0.84 mm. (8)
Distance between points on anterior margin........	0.33 mm. (12)	0.18 mm. (10, 8)

Agelenopsis naevia. Range of length of the spider, 15 mm. to 8 mm.

	Maximum	Minimum
Width of atrium............	1.26 mm. (15, 17)	0.78 mm. (15)
Length of atrium...........	0.45 mm. (14, 17)	0.24 mm. (16)
Width of pouch.............	0.66 mm. (14, 15, 16, 17)	0.54 mm. (14,15,16,17,18)
Greatest length of epigynum	2.34 mm. (14)	1.74 mm. (14)
Length of lip...............	0.30 mm. (14, 15, 16)	0.18 mm. (13, 15, 17)

Agelenopsis americana. Range of length of the spider, 15 mm. to 8 mm.

	Maximum	Minimum
Width of atrium............	0.72 mm. (13, 15)	0.42 mm. (9)
Length of atrium...........	0.42 mm. (10, 12, 14)	0.30 mm. (8, 10, 11)
Width of pouch.............	0.48 mm. (12, 14)	0.30 mm. (9, 10, 11)
Greatest length of epigynum	1.14 mm. (13, 15)	0.84 mm. (9)

Agelenopsis utahana. Range of length of the spider, 11 mm. to 6 mm.

	Maximum	Minimum
Width of atrium............	0.54 mm. (10)	0.33 mm. (6)
Length of atrium...........	0.18 mm. (10, 11)	0.12 mm. (6, 7, 9, 10)
Width of pouch.............	0.18 mm. (9, 10, 11)	0.09 mm. (7, 10)
Greatest length of epigynum	1.11 mm. (6, 9)	0.84 mm. (7, 9, 10, 11)
Distance between points on anterior margin........	0.27 mm. (10)	0.18 mm. (6, 7, 9)

Petrunkevitch (1925) suggested the epigynum of *Agelena naevia* to be quite variable and of two types, one larger and more complicated than the other. Of the four types described in this paper his two types probably present the greatest extremes in the series. His figures 1 and 2 of Plate I (page 573) are dorsal and ventral views of his small variety and are of *americana* while figures 3 and 4 of the same plate are of *naevia* of this series. They are not large and small types of the same species but two distinct species. He suggests that (page 571) "all parts of the male external reproductive organs are subject to considerable variation." Again, these structures may vary within limits in a species but the embolus and conductor of *naevia* are so different from those of *americana* that the two are easily separated. He does not figure the palp of *americana* but does give a lateral view of a palp with a long embolus which is *naevia* (text figure, page 569). The males of the two other forms used in this study (*emertoni* and *utahana*) also can be identified as separate species by the differences in these two structures.

Comstock (1912) does not figure the epigynum of an agelena in his spider book, but suggests that the epigynum of the female is quite variable as well as the palp of the male. He does figure two types of palps which he labels as variations of *naevia*. Neither of these figures (Figs. 665 and 666, page 587) is of the *naevia* suggested in this paper. In the revised edition of the Spider Book, Gertsch (1940) labels these same two figures *pennsylvanica* and *potteri*. The figure showing the long embolus, according to Comstock, is called *potteri* by Gertsch and the short form is labeled *pennsylvanica*. The *pennsylvanica* is the same as *americana* of this series while the other is the type form of the genus Agelenopsis (Giebel), called *albipilis* by him and found to be synonymous with *potteri* by later authors (Chamberlin and Ivie, 1935). *Potteri* was described by Blackwell in 1846 while *albipilis* did not appear until 1869. This species has not been taken by the author in the state of Ohio.

The eye patterns of the European form *Agelena labyrinthica* and of the American forms are different. The trochanters of the American forms are without a notch. The males of the American forms are without distinct apophyses on the tibia, but possess a long embolus and a distinctive conductor. The epigyna of the American types differ markedly from *labyrinthica*, as figured by Petrunkevitch, as well as those figured by Cambridge. From these facts it is evident that these forms, each possessing definite characters, are different genera.

Since the study of a large number of specimens of the genus Agelenopsis showed that the individuals, both males and females, can be separated on the basis of a few structures—the condition of the embolus and conductor in the male, and the shape of the vulva in the females, into four groups, and that these characters are different and relatively constant for each group, it suggests that there are four distinct species in this complex.

It is obvious, therefore, from the material presented that we have been dealing with more than one species of spider.

CONCLUSIONS

1. The genus Agelenopsis, erected by Geibel, includes the Amèrican forms which differ from the genus Agelena representing the European species.

2. The specific name *A. americana* (Keyserling) is to be used in preference to *A. pennsylvanica* (C. Koch).

3. The epigynum of the female and the palp of the male are specific characters for these members of the genus Agelenopsis.
   a. The shape of the vulva of the epigynum is constant and distinctive for each species.
   b. The appearance of the conductor and embolus of the male palp is constant and distinctive for each species.
   c. While the length of the spider of a species is quite variable, the structures of the copulatory apparatus are fairly constant in size.

4. The descriptions of the epigyna of the two extreme variations of *naevia*, as given by Petrunkevitch, are correct.

5. These two variations, recognized by Petrunkevitch, are to be established as two distinct species, namely: *A. americana* and *A. naevia*.

6. There are four well founded species of the genus Agelenopsis occurring in the state of Ohio.

7. Descriptions and figures of the male palp and the epigynum of *Agelenopsis naevia* (Walckenaer) as a distinct species probably are given here for the first time.

LITERATURE CITED

Blackwell, John. 1846. Notice of Spiders captured by Professor Potter in Canada, with descriptions of such Species as appear to be new to science. Ann. Mag. Nat. Hist., Vol. 17 (Series 1), pages 30–44. (Desc. of *A. potteri*).

Cambridge, O. P. 1897–1905. Biologia Centrali Americana. Vol. 2, page 334. (Recognition of the genus Agelenopsis).

Chamberlin, R. V. and **Gertsch, W. J.** 1929. New Spiders from Utah and California. Jour., Ent. and Zool., Pomona College. Vol. 21, pages 101–117. (Suggests Hololena as a sub-genus of Agelena, page 105).

Chamberlin, R. V. and **Ivie, Wilton.** 1933. Spiders of the Raft River Mountains of Utah. Bull. Univ. Utah. Vol. 23, No. 4, pages 1–79. (Desc. *A. utahana* p. 43. Figs. epigynum and palp).

Chamberlin, R. V. and **Ivie, Wilton.** 1935. Miscellaneous New American Spiders. Bull. Univ. Utah. Vol. 26, No. 4, pages 1–79. (Desc. of *A. emertoni.* p. 33. Genus Agelenopsis recognized).

Comstock, J. H. 1912. The Spider Book. Doubleday, Page & Co. (Genus Agelena, pages 585–592).

Emerton, J. H. 1890. New England Spiders of the Families Drassidae, Agelenidae, and Dysderidae. Trans. Conn. Acad. Arts and Sci., Vol. 8. (Variations of *A. naevia*, pp. 34–35).

Gertsch, W. J. 1940. The Spider Book. Doubleday, Page & Co. (Figs. 665, 666, of *A. potteri, A. pennsylvanica*).

Giebel, C. G. 1869. Ueber einige Spinnen aus Illinois. Zeit. fur die Ges. Natur. Her. von dem Natur. Vol. 33, pages 248–252. (Genus Agelenopsis and *A. albipilis*).

Keyserling, E. G. 1877. Spinnen aus Uruguay und einigen anderen Gegenden Amerikas. Wein Zool.-Bot. Ges. Vol. 27, pages 571–624. (Desc. *A. americana*, p. 599. Figs. palp and epigynum).

Koch, C. L. 1843. Die Arachniden, Vol. 10. (Desc. *A. pennsylvanica*, p. 111, fig. 828).

Petrunkevitch, A. 1925. External reproductive organs of the common grass spider, *Agelena naevia* Walck. Jour. Morph. and Physiol. Vol. 40, No. 3.

Petrunkevitch, A. 1933. An Inquiry into the Natural Classification of Spiders, Based on a Study of their Internal Anatomy. Trans. Conn. Acad. Arts and Sci. Vol. 31.

Simon, Eugene. 1898. Histoire Naturelle des Araignées. Vol. 2, 2nd Ed. (Desc. of genus, pages 220, 250–251, 254, 258).

White, Adams. 1841. Descriptions of new or little known Arachnida. Ann. Mag. of Nat. Hist. Vol. 7 (Series 1), pages 471–477.

Wynkoop, J. R. 1939. A Technique for Sectioning and Staining the Epigyna of the female grass spider *Agelena naevia* (Walck.). Master's Thesis, Ohio State University.

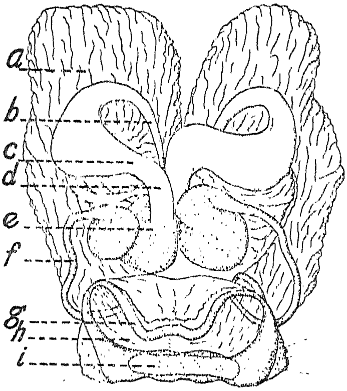


Fig. 1

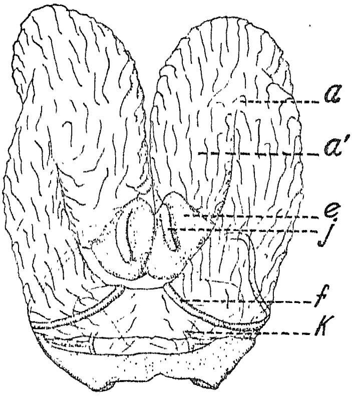


Fig. 2

A. naevia

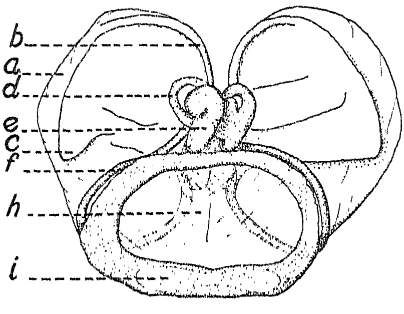


Fig. 3

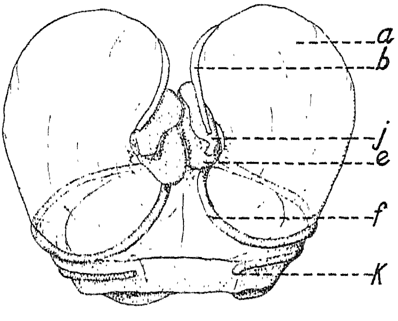


Fig. 4

A. americana

Fig. 1. Ventral view of dissected epigynum of *Agelenopsis naevia*.
Fig. 2. Dorsal view of same.
Fig. 3. Ventral view of dissected epigynum of *Agelenopsis americana*.
Fig. 4. Dorsal view of same.

(All epigyna and palps drawn to the same scale.)

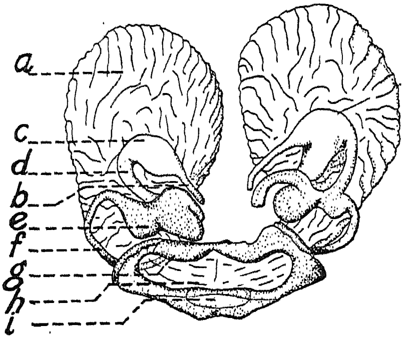


Fig.5

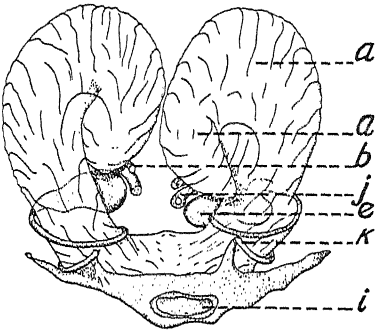


Fig.6

a. utahana

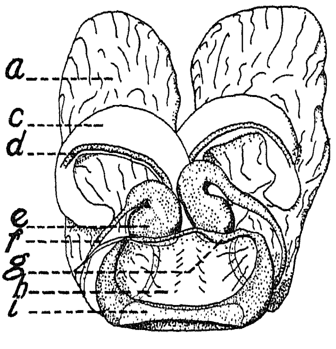


Fig.7

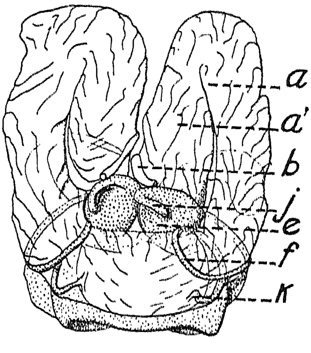


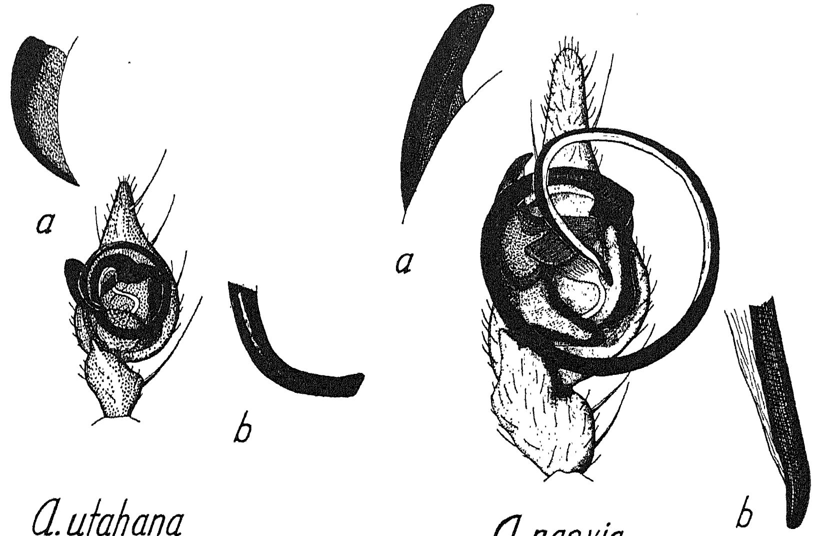
Fig.8

a. emertoni

Fig. 5. Ventral view of dissected epigynum of *Agelenopsis utahana*.
Fig. 6. Dorsal view of same.
Fig. 7. Ventral view of dissected epigynum of *Agelenopsis emertoni*.
Fig. 8. Dorsal view of same.

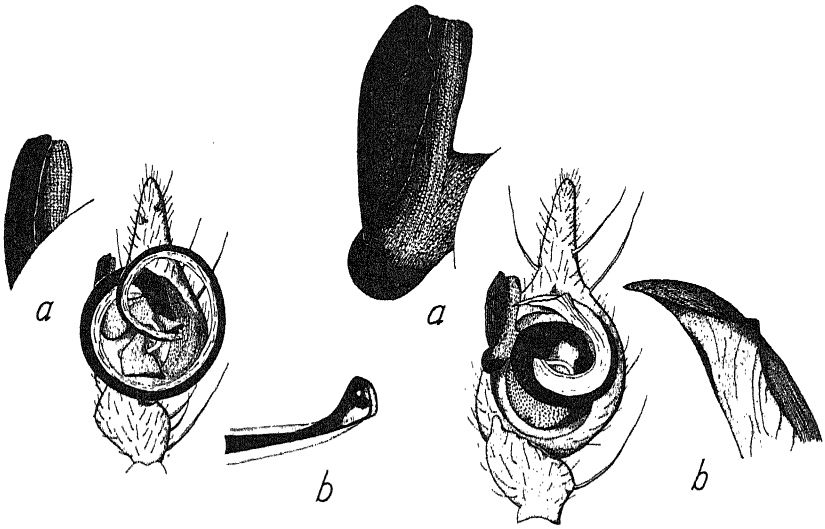
The structures in the above figures are indicated by letters.

a. Copulatory sac.
a'. Reverted portion of copulatory sac.
b. Blind tube of the diverticle.
c. Diverticle.
d. Tube connecting the diverticle with the seminal receptacle.
e. Seminal receptacle.
f. Fertilization tube.
g. Projections on the anterior edge of the vulva.
h. Atrium.
i. Pouch in the posterior margin of the vulva.
j. Blind tube of seminal receptacle.
k. End of the fertilization tube.



A. utahana

A. naevia



A. emertoni

A. americana

Ventral views of the right palps of *A. utahana*, *A. naevia*, *A. emertoni* and *A. americana*.

a. Enlarged figures of the conductor.
b. Enlarged figures of the tip of the embolus.

THE SENSITIVITY OF ANEMOMETER CUPS

JOHN G. ALBRIGHT
AND
G. E. KLEIN,
Case School of Applied Science,
Cleveland, Ohio

INTRODUCTION

The question as to which type of anemometer cup should be universally accepted as the standard type cup has long been disputed by those interested in the question. At the present time the organizations interested in questions involving the use of anemometers employ varied types of anemometer cups on their instruments and frequently change to a different type in the hope of obtaining better results.

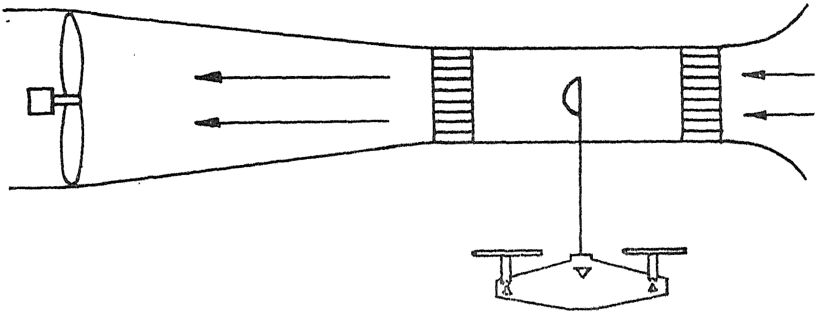


Fig. 1. Sketch of Wind Tunnel.

Studies have been made by various investigators as to the comparison of different type of cups best suited for their individual needs, but little has been done to compare the relative merits and disadvantages of various types of cups from comparable points of view.

It has been, therefore, the object of this investigation to study and determine the points of similarity and contrast of various cup shapes and to arrive at some conclusion as to the best cup shape or shapes which will give the maximum sensitivity in an anemometer.

APPARATUS

The apparatus used consisted of two parts, namely, a wind tunnel and the various cup shapes themselves. The wind tunnel used was of sufficient size to accommodate the cup shapes and was of such construction that accurate control of the wind velocity could be maintained. A sketch of the wind tunnel and the cup shape when in position is illustrated diagrammatically in Figure 1.

The wind velocity created inside of the tunnel was measured by a pitot tube pressure gauge which had previously been completely calibrated against a vane type anemometer. The force on the specimen was measured by means of an aerodynamic balance similar in construction to a laboratory platform balance.

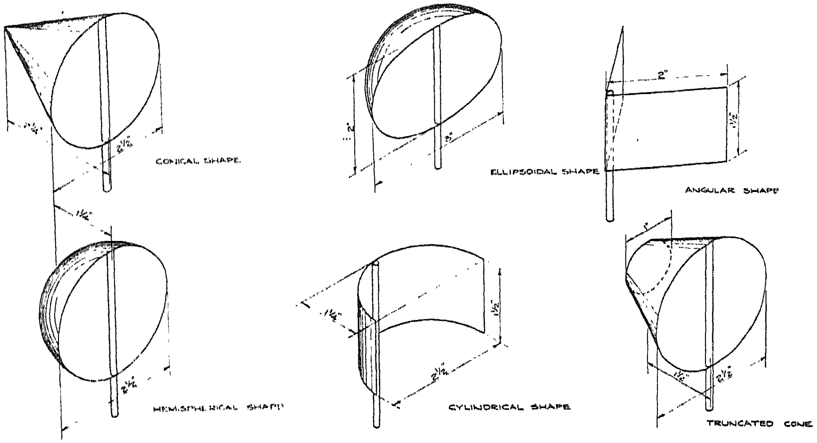


Fig. 2. Anemometer Cup Shapes.

The apparatus which was tested consisted of seventeen different cups comprising six general forms. The shapes tested were as follows: (1) angular shaped cups bent at angles of 15°, 30°, 45°, etc., ranging from 15° to the 180° straight angle; (2) truncated conical shape; (3) regular conical shape; (4) hemispherical shape; (5) ellipsoidal shape; and (6) cylindrical shaped cups. Diagrams of the various shapes with dimensions are shown in Figure 2. Each of the cup shapes was mounted on an arm and placed in position inside of the wind tunnel as indicated in Figure 1.

PROCEDURE

After the cup shapes had been mounted in position, the wind tunnel was turned on and data recorded of both the wind velocity and the corresponding force on the sample. Readings of the wind velocity were taken on the pressure gauge at appropriate steps from zero wind velocity to the capacity of the wind tunnel, which was 16.23 miles per hour velocity. The corresponding forces were measured on the aerodynamic balance.

The cups were completely tested in one direction and then turned around 180°, so that the other side of the cup faced the wind flow. Complete readings were again taken. The force against the cup and force with the cup mean the force produced when the wind blows against the interior of the cup and the force produced against the exterior of the cup respectively as illustrated in Figure 3.

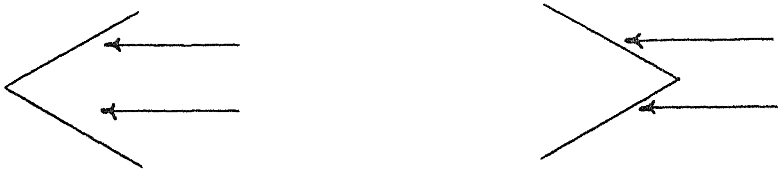


Fig. 3. Wind Forces against the cup (left) and with the cup (right).

Plots were then made to show the relationship between the force and the wind velocity in each case. Sample sets of curves are represented in Figures 4 to 8. In these graphs, the circular figures pertain to the values of the force against the cup, while the solid dots represent the values of the force with the cup.

RESULTS

On the basis of the results presented in the curves, it is possible to arrive at a conclusion as to the most sensitive cup tested. Following the line of reasoning that the force against the cup would be greater than the force with the cup at the same wind velocity in order for the cup system of an anemometer to rotate, it becomes evident that the cup which exhibits the greatest difference in force on the front and on the back of the cup (or force against and force with the cup respectively) for the same wind velocity would be the most sensitive cup.

TABLE I

Force Differences

Cup Shape	0–8 miles/hour	8–12 miles/hour	12–16 miles/hour
Ellipsoid	3.3	9.2	15.1
Cone	2.5	6.5	11.8
Hemisphere	2.4	7.7	14.9
105° Angle	3.2	6.5	8.4
90° Angle	2.9	6.0	11.3

For the purpose of comparison of the cups, the region for the wind velocity was divided into three parts, namely, that region representing 0 to 8 miles per hour velocity, that representing 8 to 12 miles per hour, and that representing 12 to 16 miles per hour velocity. The corresponding values for the differences in force were then recorded. Such data are presented in Table I.

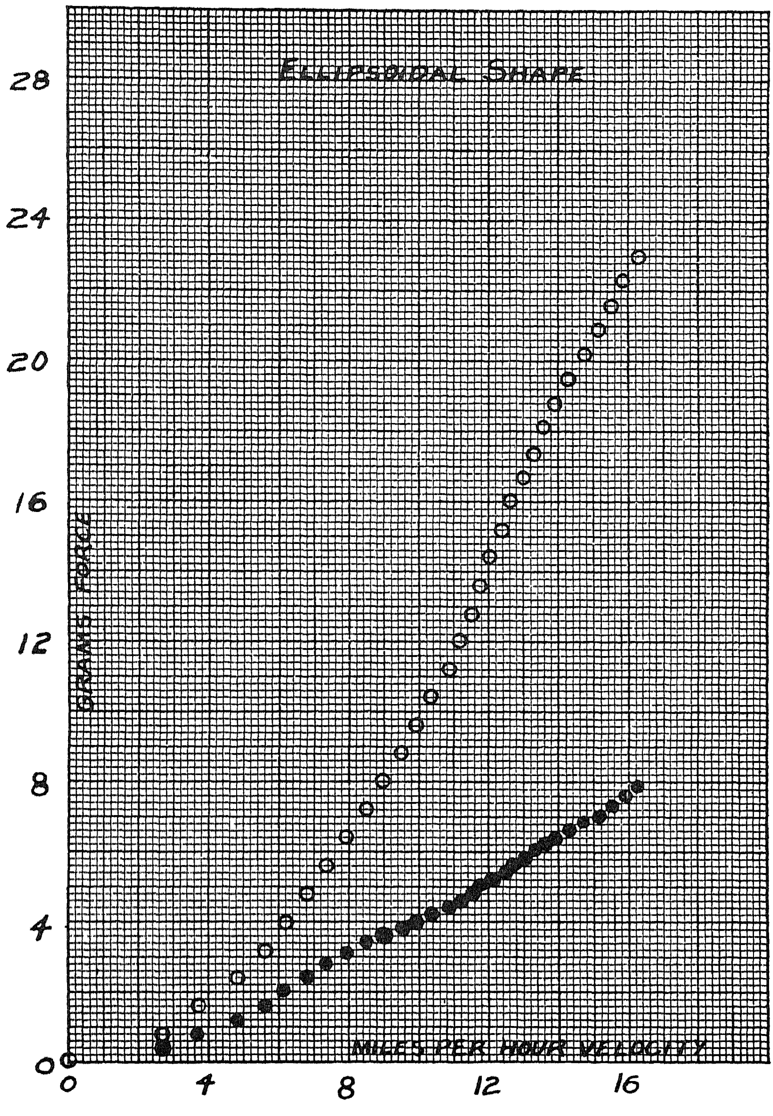


Fig. 4. Relation between force and wind velocity with ellipsoidal cup.

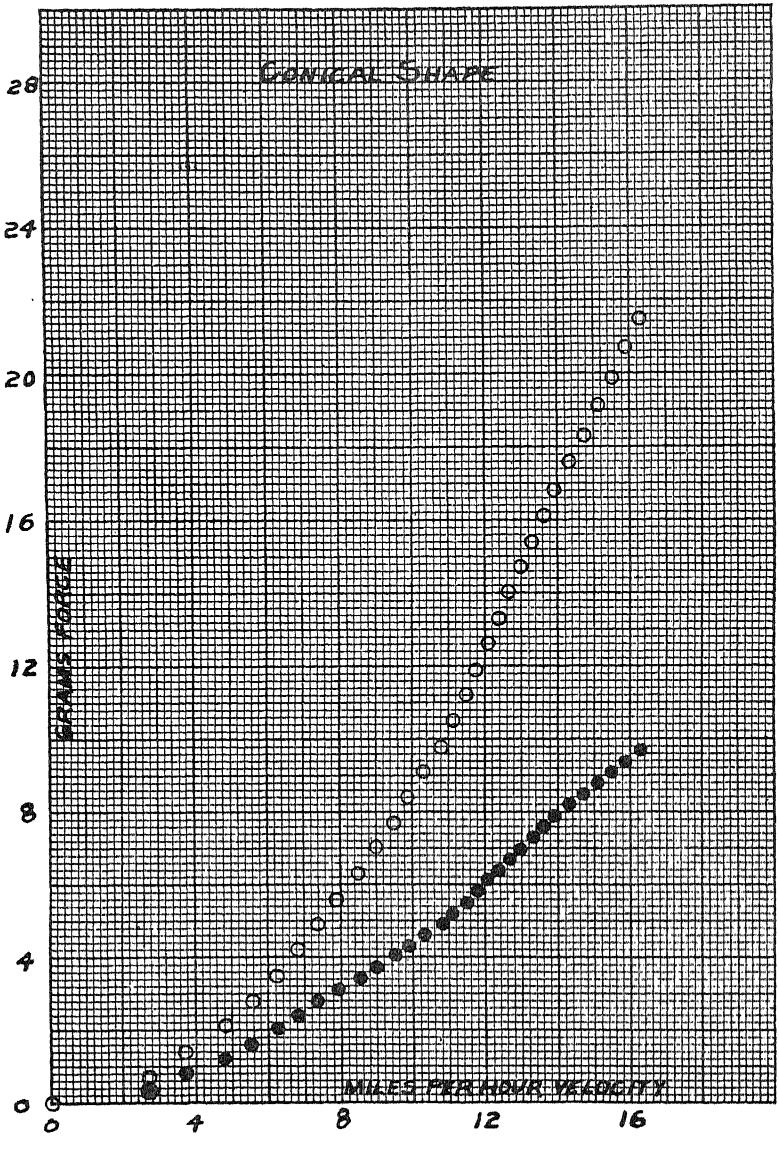


Fig. 5. Relation between force and wind velocity with conical cup.

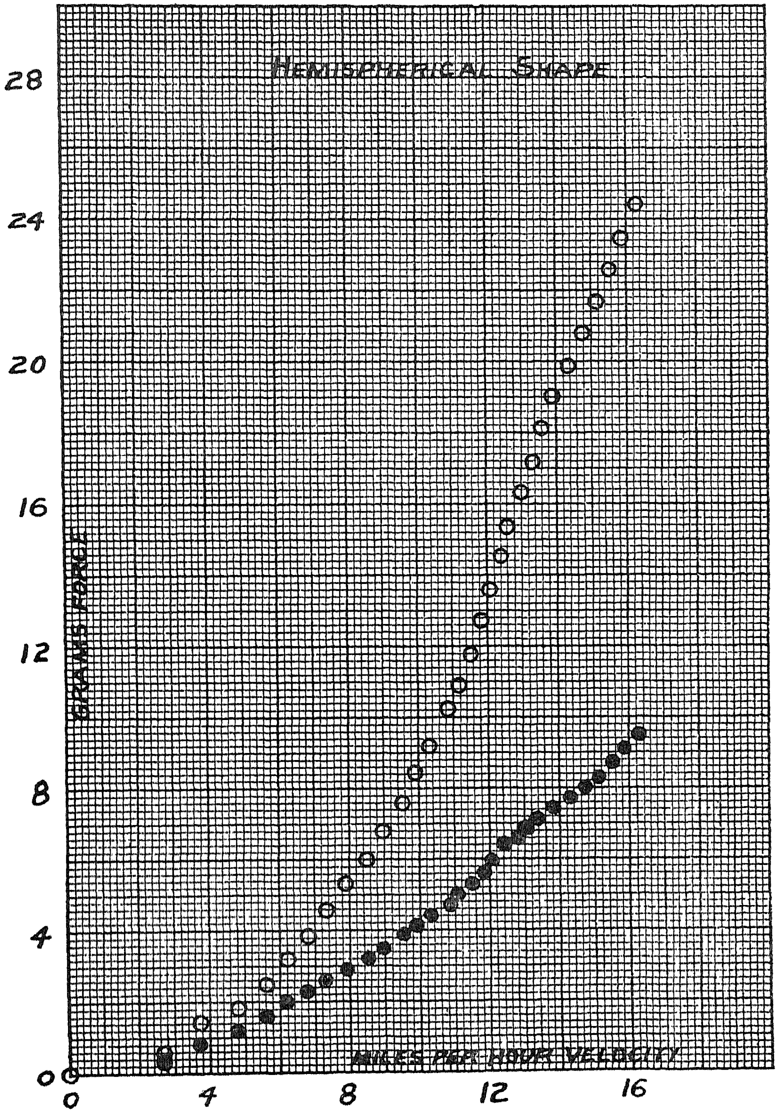


Fig. 6. Relation between force and wind velocity with hemispherical cup.

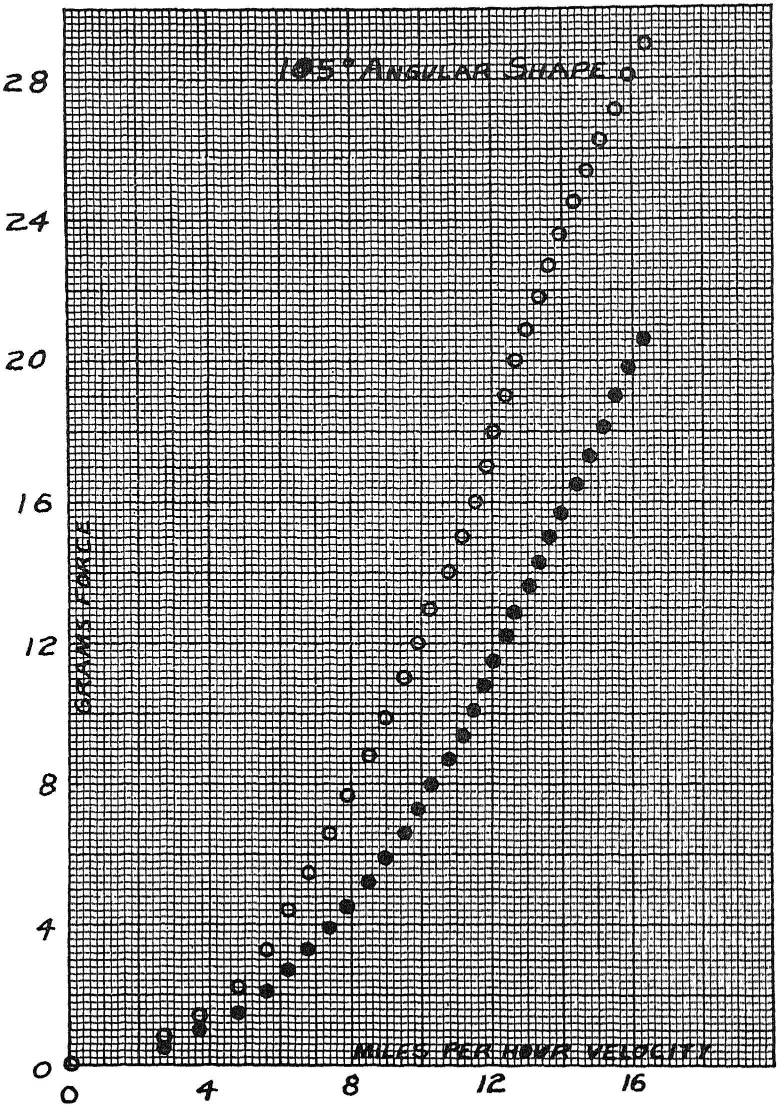


Fig. 7. Relation between force and wind velocity with 105° angular cup.

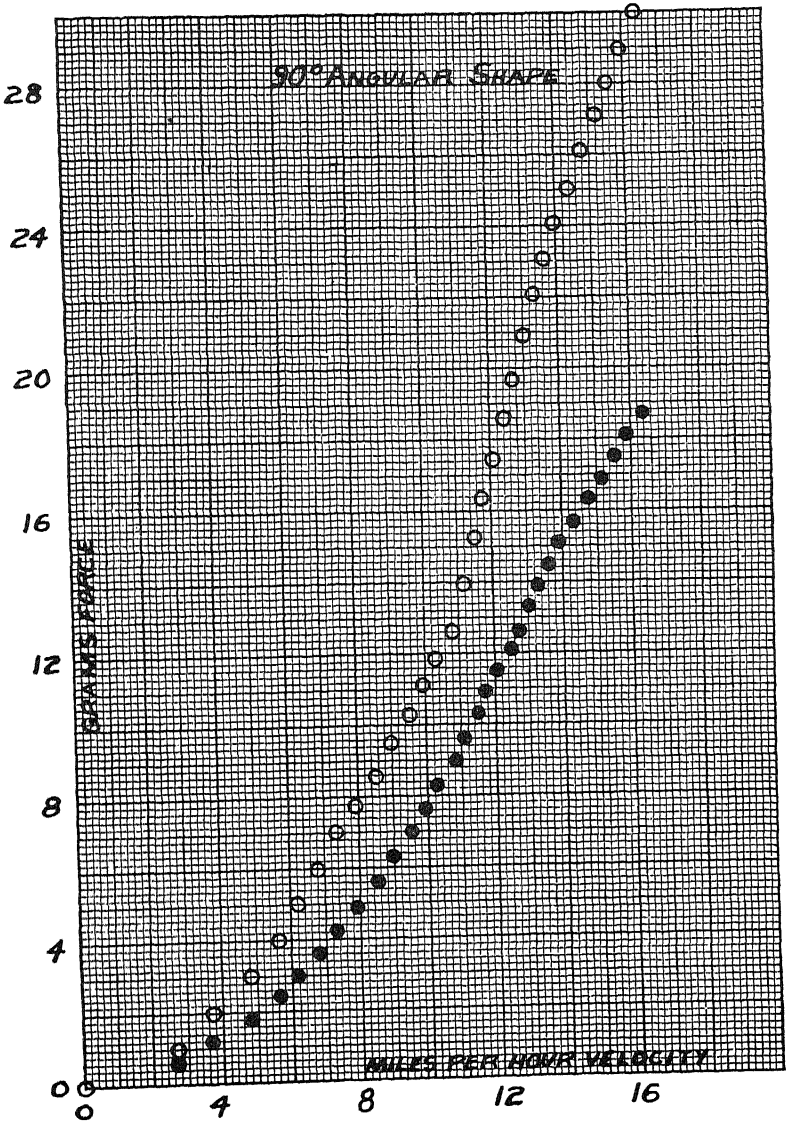


Fig. 8. Relation between force and wind velocity with 90° angular cup.

SUMMARY

From the results obtained, the conclusions of this investigation may, therefore, be summarized as follows:

(1) The ellipsoidal shaped cup is the most sensitive over the entire range tested.

(2) The conical shaped cup is fairly sensitive in both the lower and middle regions.

(3) The hemispherically shaped cup is fairly sensitive over the entire range, being only slightly less sensitive than the ellipsoidal shaped cup.

(4) The 105° angular shaped cup is very sensitive in the lowest region and fairly sensitive in the middle region.

(5) The 90° angular shaped cup is fairly sensitive over the entire region.

The entire procedure was then repeated with beaded cups. These cups were identical with those previously described with the addition of a slight beading along the outer edges. The results obtained from the testing of these shapes shows that the sensitivity of an anemometer cup is not improved by adding a bead to the cup.

BIBLIOGRAPHY

(1) **Marvin, C. F.** Recent Advances in Anemometry. Monthly Weather Review 62, 115 (1934).

(2) **Shaw, A. N.** Notes on the Comparison of Anemometers Under Open-Air Conditions. Monthly Weather Review 47, 21 (1919).

(3) **Fergusson, S. P.** The Sensitiveness of Anemometers. Bulletin of the American Meteorological Society 15, 95 (1934).

BUTOMUS UMBELLATUS IN AMERICA*

EARL L. CORE,
Franz Theodore Stone Laboratory,
Put-in-Bay, Ohio

During the summer of 1939 I discovered *Butomus umbellatus* growing as a very abundant plant along the gravelly or marshy shores of most of the larger islands in the western end of Lake Erie. This handsome and interesting plant is not treated in the 7th edition of Gray's Manual and its occurrence here in such abundance led me to investigate the literature dealing with its distribution in America.

This plant, commonly called in France "Jonc fleuri," is classified by some botanists in the Alismaceae but on account of its nine stamens and usually six carpels is treated as a separate family by Gaston Bonmer in his "Flora Complete de la France." It is indigenous in Europe in marshes and along borders of streams and lakes from Italy northward to Norway. According to Dr. Leo H. Grindon it is one of the handsomest plants that England produces.[1] Thomé gives a good colored plate in his "Flora von Deutschland," vol. 1, page 84 (1886).

According to Fr. Marie-Victorin,[2] "elle parait avoir été observée pour la premiere fois à Laprairie,[3] vers 1897, par le F. Euphrosin." So far as is known, the first specimens were collected in 1905, at Laprairie on the flats ("battures") of the St. Lawrence River by Bros. Marie-Victorin and Rolland-Germain.[4] A specimen in the Britton Herbarium at the New York Botanical Garden was collected September 16, 1906, by Fr. Louis Arséne on the borders of the St. Lawrence River, where he says it was common from Caughnauaga to Sorel, near Montreal.

An appearance along the canal at Ottawa as early as 1906 was reported by E. H. Blackader.[5] The same year it was found at Beauharnois, Valois, and Longueuil and in 1907 at Chateauguay by L'Abbé V.-A. Huard, who recognized it at sight, presumably from his acquaintance with it in Europe.[6]

---

*Contribution No. 19 from the Herbarium of West Virginia University.

[1] Fletcher, "Two newly introduced European plants". *Ottawa Naturalist* 22: 80, 81, 1908.

[2] "Flore Laurentienne" (1935), p. 618, footnote.

[3] Opposite Montreal.

[4] Fletcher, loc. cit.

[5] *Ottawa Naturalist*, December, 1908.

In 1908 Fletcher[7] reported that Fr. Marie-Victorin believed that it also grew around the Boucherville Islands a few miles above Longueuil. It seemed certain (he said) that it ripened its seeds at Longueuil, in spite of the late date at which the water recedes from the river flats, preventing its appearance above the surface until late in June. It was found associated with *Scirpus americanus*, *Zizania aquatica*, *Potentilla anserina*, *Mentha canadensis*, *Xanthium canadense*, *Lycopus virginicus*, *Sagittaria variabilis*, etc.

Nash, in 1909, in "North American Flora," said it was "introduced along the shore of the St. Lawrence, near Montreal, Quebec" (Vol. 17, p. 63).

In 1913 it was still so uncommon that Britton and Brown, in the second edition of the "Illustrated Flora," dismissed it summarily by the following note, inserted immediately after their treatment of the Alismaceae: "*Butomus umbellatus* L., a plant of the related family Butomaceae, with many-ovuled ovaries, rose-colored flowers and narrow ensiform leaves, a native of Europe and Asia, has been found on the shores of the St. Lawrence River, near Montreal."[8]

In 1918 Fr. Marie-Victorin reported that it covered "broad flats at least from Chateauguay to Nicolet" and was "especially abundant about Montreal." That it spreads rapidly, he says, "is shown by its conquest of this large domain in less than forty years. It has not been reported elsewhere in America."[9]

In 1922 specimens were collected on a wet stony beach at Lachine by Judge J. R. Churchill and in the "zone intercotidale de la grève de Beauport," near Quebec, by Fr. Rolland. Their collections are preserved in the Gray Herbarium of Harvard University.

The thrill that has by now been experienced by many American botanists upon the discovery of *Butomus* was ably described by Knowlton in 1923: "While collecting plants along the St. Lawrence River at Ste. Angèle de Laval, opposite Three Rivers, Quebec, the last day of July, Mr. Edward B. Chamberlin and I were much surprised to find in the swampy land near the shore a striking endogenous plant that neither of us had seen nor heard of before. Good specimens were a meter tall, with an umbel of large pink flowers, veined with darker red. . . . We soon discovered that the plant did not fit the ordinary key to the endogens, for the flower had three colored sepals, three larger petals, *nine* stamens, and six *separate* carpels."[10] Knowlton reported also finding it at Pointe du Lac, Berthierville, St. Sulpice, and Ste. Lambert.

---

[6] "Addition à la flore d'Amerique," *Le Naturaliste Canadien*, 35: 65-67, May, 1908.

[7] Fletcher, loc. cit.

[8] Vol. 1, p. 104.

[9] *Revue Trimestrielle Canadienne* 263, November, 1918.

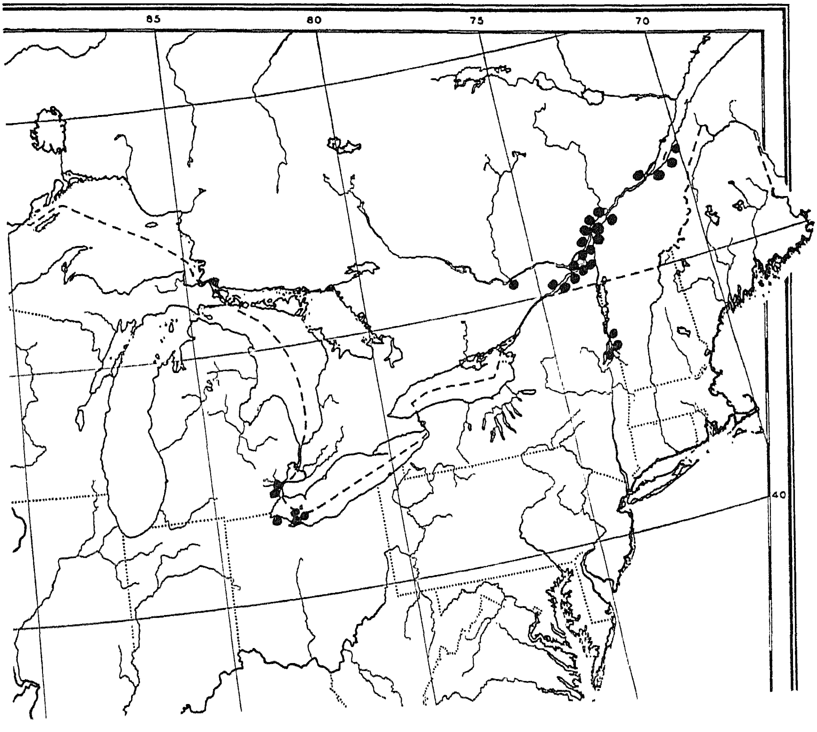


Fig. 1. Map showing recorded distribution of *Butomus umbellatus* in America.

The remarkable manner in which this introduced species has taken its place, ecologically, in the flats along the St. Lawrence is discussed by Fr. Marie-Victorin in 1929: "Le Butome, . . . l'une des dernieres acquisitions de la flore du Quebec, en moins de quarante ans a conquis les grèves du Saint-Laurent, depuis le lac Saint-Louis jusqu'aux abords de la ville de Quebec, et l'espèce est particulièrement envahissante dans la region de Montrèal où elle semble être apparue pour la premiere fois. Avec les années, elle regnera presque seule, semble-t-il, sur nos rivages plats au moins dans certaines conditions écologiques. C'est un bel exemple du bouleversement qui peut être opéré dans une flore par une seule espèce quand elle est bien outillée et qu'elle se transporte en territoire nouveau en laissant derrière elle la horde de ses ennemis, un bel exemple de dynamisme violent dans le temps et dans l'espace.''[11]

---

[10] "*Butomus umbellatus* on the St. Lawrence River," *Rhodora* 25: 220, 221. 1923.

The first record of *Butomus umbellatus* for the United States was published by Knowlton, who found it on August 11, 1929, well established and flourishing on the South Bay of Lake Champlain, at Dresden, Washington County, New York, near the bridge from Whitehall.[12] Five days later, on August 16, Muenscher found it very abundant along South Bay, ''on clay flats and in water up to one meter deep;'' also, later in August, at Whitehall, ''along the border of a mill pond and along the Champlain canal from Whitehall northwards for about ten miles to the Dresden Narrows in Lake Champlain.'' The first record for Vermont was reported by the same observer, who found it in ''Rutland County along the shore of Lake Champlain northward to the Dresden Narrows, and in Addison County along the outlet of East Creek.''[13]

The next year (1930) Farwell collected it in Wayne County, Michigan, in Brownstown Township on August 26 and at River Rouge on September 9. Farwell notes: ''This species has long been naturalized in the vicinity of Detroit and southward. I am informed on good authority that it was well established before the present century and that it covered acres of marshes at River Rouge before the operations of the Ford Motor Co. in this region reclaimed the marshland and destroyed the better part of the stand. There is nothing to prove or disprove the belief that the plant was brought over by Cadillac's party more than three centuries ago and that it has been here ever since.''[14] Marie-Victorin, however, doubts that *Butomus umbellatus* was in Detroit during the French regime, believing that its first introduction ''took place about fifty years ago on the St. Lawrence somewhere near Montreal."[15] In a paper presented at the 6th Congress of *L'Association Canadienne-francaise pour l'avancement des Sciences*, at Trois-Rivieres, in 1938, he "discute cette hypothèse et en montre l'invraisemblance."[16]

---

[11] ''La dynamisme dans la flore du Quebec,'' *Contrib. Lab. Bot. Montreal* 13: 83, 84. 1923.

[12] ''*Butomus umbellatus* at Lake Champlain,'' *Rhodora* 32: 18, 19. 1930.

[13] ''*Butomus umbellatus* in the Lake Champlain Basin,'' *Rhodora* 32: 19, 20. 1930.

[14] Papers of the Michigan Academy of Science, Arts and Letters, 23: 125. 1937 (1938).

Writing in 1932, Fernald listed *Butomus umbellatus* as one of the characteristic plants of the St. Lawrence estuary.[17]

In Marie-Victorin's "Flore Laurentienne," published in 1935, in a chapter on "Facteurs Dynamiques Extrinseques" there is a map, "Carte R," showing the "Extension du *Butomus umbellatus* sur le Saint-Laurent, a la fin de l'année 1933." On page 618 of that work there is a description of the plant and a footnote states: "Jusqu'aux present, le Butome a conquis les rivages du Saint-Laurent depuis le lac Saint-François jusqu'a l'eau salée (St. Jean-Port-Joli). Il remonte aussi les affluents: Richelieu, Nicolet, St. François. Le Butome s'avance en eau profonde sous une forme sterile à longues feuilles dont les extremites deviennent flottantes à la fin de la saison; cette forme d'eau, f. vallisneriifolius (Sagorski) Glück, est un obstacle serieux à la petite navigation d'agrement, dans la region montrealaise. La rapidité de cette conquête s'explique par l'abondance des graines, multiplication vegetative un moyen des rhizomes tracants et des bulbilles et par l'action de la glace qui enroue les rhizomes superficiels et les transporte au loin au moment de la debâcle."

In a discussion of some phytogeographical problems of eastern Canada, in 1938, Marie-Victorin relates the story of its introduction: "Then appeared, nobody knows how, a short time before 1900 probably, a hardy and beautiful Alismaceous plant, *Butomus umbellatus*, the Old World flowering rush. Spreading very rapidly by means of its seeds, rootstocks, and bulblets, it has refreshed the rather dull purple of *Lythrum Salicaria* and painted anew the shoals with the mass effect of multitudinous pink umbels."[18] Illustrations accompanying his article show pure stands of the plant growing on shoals of the St. Lawrence, and a close-up of the rootstock, "bearing numerous pea-size bulblets," which "powerful means of dispersal partly accounts for" its rapid conquest of the region.

---

[15] Letter to the author, January 2, 1940.

[16] "Le *Butomus umbellatus* etait-il dèjá en Amérique au XVIIe siecle?" An abstract of the paper appears in the proceedings of the Congress.

[17] "*Callitriche stagnalis* on the lower St. Lawrence," *Rhodora* 34: 39. 1932.

[18] "Phytogeographical problems of eastern Canada," *Amer. Midl. Nat.* 19: 489–558. 1938. See especially pages 555–557.

The first collection of *Butomus* in Ohio was made by Louis W. Campbell at Little Cedar Point, Jerusalem Township, Lucas County.[19] Two additional Ohio counties, Ottawa and Erie, were recorded by the author in 1939.

Butomus umbellatus forma *vallisneriifolius* (Sagorski) Gluck, a sterile deep-water form with long leaves the ends of which float on the surface, was collected at Longueuil on September 12, 1931, by Marie-Victorin and Rolland-Germain,[20] and occurs elsewhere.

In addition, it should be noted that *Butomus* has been extensively introduced in numerous lake regions, particularly in New York, and may be expected to be encountered as a thoroughly established plant over a rapidly widening area. As far south as Morgantown, W. Va., it grows and flowers abundantly in the garden of Dr. H. A. Davis.

A good brief description and a sketch appear in Fassett's "Manual of Aquatic Plants,"[21] published in 1940.

The present known distribution of this species in North America, excluding the areas in which it is known to have been planted, may now be summarized as follows:

QUEBEC: L'Islet Co.: St. Roch-des-Aubrets, *Marie-Victorin* et al 43059, July 26, 1935. Montmagny Co.: Cap St. Ignace, *Marie-Victorin* et al 33195, July 15, 1930. Bellechase Co.: Anse St. Vallier, *Fernald* 2507, September 15, 1931. Quebec Co.: Beauport, *Rolland-Germain* 16028, August 8, 1922. St. Maurice Co.: Trois Rivières, *Stanislas;* Pointe du Lac, *Knowlton and Chamberlain,* August 2, 1923. Nicolet Co.: Ste. Angele-de-Laval, *Knowlton and Chamberlain,* July 31, 1923. Berthier Co.: Berthier, *Bonin* 261, June 26, 1931. Richelieu Co.: Ile aux Corbeaux, *Marie-Victorin* 16029, August 22, 1922. Tamaska Co.: *Adrien* 1215, July 17, 1926. L'Assomption Co.: St. Sulpice, *Boivin* 200, August 24, 1935. Chambly Co.: Longueuil, *Marie-Victorin* and *Rolland-Germain* 43815, October 5, 1934. Laprairie Co.: Laprairie, *Marie-Victorin* and *Rolland-Germain,* in 1905; La Tortu, *Fernald* 2507, September 19, 1931. Montreal

---

[19] In Schaffner's "Additions to the Revised Catalog of Ohio vascular plants. I." *Ohio Journ. Sci.* 33: 288. 1933.

[20] Memoires et Compte rendus de la Societe Royale du Canada III. 28: 1–17. 1934.

[21] Pages 93, 96.

Co.: Ile-Ste.-Hélène, *Boivin* 178a, August 18, 1935. Jacques-Cartier Co.: Lachine, *Churchill*, in 1922; Valois, *Huard*, in 1906. Chateauguay Co.: Chateauguay, *Huard*, in 1907. Beauharnois Co.: Beauharnois, *Huard*, in 1906.

ONTARIO: Glengarry Co.: Rivière Raisin, *Marie-Victorin*, *Rolland-Germain*, and *E. Jacques* 46741, August 9, 1932. Russell and Carleton Cos.: Environs of Ottawa, *Blackader* in 1906; *Rolland-Germain* 16027, June 27, 1921.

VERMONT: Rutland Co.: Dresden Narrows, *Muenscher*, in August, 1929. Addison Co.: East Creek, *Muenscher*, in August, 1929.

NEW YORK: Washington Co.: Dresden, *Knowlton*, August 11, 1929; South Bay, *Muenscher*, August 16, 1929; Whitehall, *Muenscher*, August, 1929.

MICHIGAN: Wayne Co.: Brownstown Township, *Farwell* 8742, August 26, 1930; River Rouge, *Farwell* 8759, September 9, 1930.

OHIO: Lucas Co.: Little Cedar Point, *Campbell*. Ottawa Co.: Gibraltar Island, *Core* 7098, June 21, 1939; North Bass Island, *Core* 7300, July 6, 1939; Sugar Island, *Core*, July 25, 1939; Middle Bass Island, *Core*, August 16, 1939; South Bass Island, *Core*, August 24, 1939. Erie Co.: Kelley's Island, *Core*, July 13, 1939.

For assistance in the collection of the data presented in this paper, I am indebted to Harold N. Moldenke, of the New York Botanical Garden; M. L. Fernald, of the Gray Herbarium; W. C. Muenscher, of Cornell University; Oliver A. Farwell, of Lake Linden, Mich.; and especially to Fr. Marie-Victorin, of the University of Montreal, who provided numerous details concerning the distribution of *Butomus* in the St. Lawrence valley.

A NEW GENUS (KNULLANA) AND TWO NEW SPECIES OF LEAFHOPPERS (HOMOPTERA-CICADELLIDAE) FROM MEXICO

DWIGHT M. DE LONG,
Ohio State University

In 1900 Dr. Ball described from a single male specimen collected in Mexico a species which he named *Thamnotettix perexigua*. Recent collecting in Mexico and the southwestern United States has brought to the author many specimens of this group which represent three distinct species. Also the present study has indicated that these do not belong to a previously described genus. The genus and two species belonging to it are therefore described and the characters of the males of the three known species are offered for their separation.

Genus **Knullana** nov.

Related to *Chlorotettix*, *Cyperanus* and *Elymanus*. Male plates with long tapering filamentous apices as in *Osbornellus*. In general form and appearance most closely resembling the larger green species of *Chlorotettix*, with banded markings on the vertex. The vertex is short and broad and bluntly angled with front. The pronotum is broader than the head. The elytra are long and narrow, venation similar to that of *Cyperanus*. Genotype *Thamnotettix perexigua* Ball.

I take pleasure in dedicating this genus to Professor J. N. Knull, who has collected so many interesting Cicadellidae in North America, especially in the southwestern United States.

Knullana perexigua (Ball)

Thamnotettix perexigua Ball. Can. Ent. 32: 339, 1900

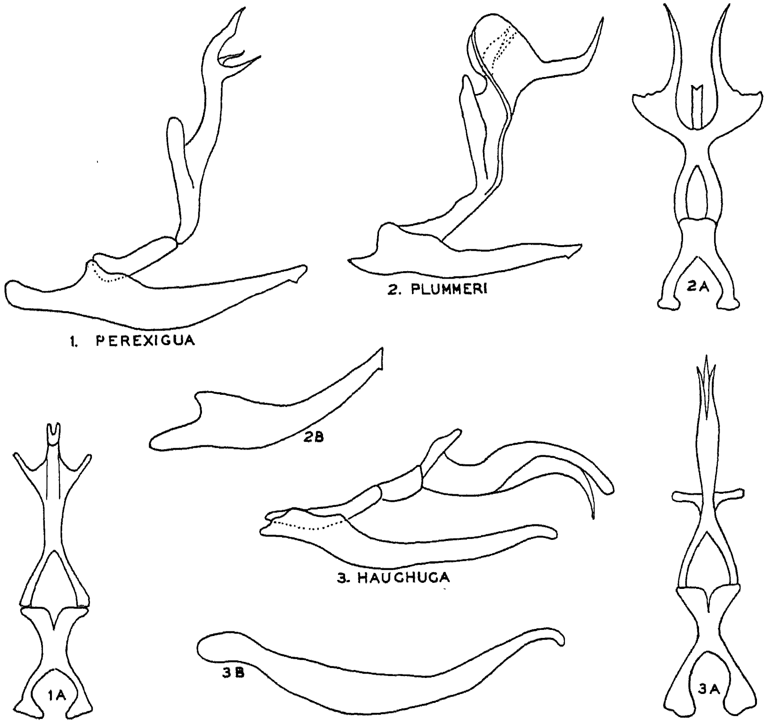
A large yellowish-green species with a black waved line above margin of vertex. Length, 8–8.5 mm.

Vertex broad, slightly longer on middle than next the eyes and more than twice as broad as long.

Color.—Yellowish-green, vertex with a black waved line above margin of vertex and a more narrow parallel line just beneath margin, forming a pale marginal band which is the width of the ocelli. Elytra greenish-yellow subhyaline, veins pale, inconspicuous. Face pale fuscous with portions of several arcs.

Genitalia.—Female last ventral segment slightly produced with a pair of long slender tapered processes arising on middle half and produced more than the length of the segment. These are separated by a deep

U-shaped notch the width of the ovipositor. Male plates long with tapered attenuate apices. Style long and rather narrow, tapered to form a rather blunt apex which bears a small tooth on inner margin. Aedeagus bifid at base with a short erect produced process at about half its length. Apex terminating in three processes, a central dorsally curved heavier portion and a ventral lateral process on either side.



1. Lateral view of style and aedeagus of *K. perexigua.*
   1a—Ventral view of aedeagus.
2. Lateral view of style and aedeagus of *K. plummeri.*
   2a—Ventral view of aedeagus; 2b—Ventral view of style.
3. Lateral view of style and aedeagus of *K. hauchuca.*
   3a—Ventral view of aedeagus; 3b—Ventral view of style.

This species was described by Ball from a single male specimen from Cuernevaca, Mexico. The allotype female is from Chilpancingo, Mexico, September 10, 1940, collected by the author.

A large series of specimens are at hand including material from Taxco, Chilpancingo, Iguala, Cuernavaca and Jiutepec, Mexico.

Knullana hauchuca n. sp.

Resembling *perexigua* in form and general appearance but smaller and darker in color. Male genitalia distinct. Length, 7–7.5 mm.

Vertex broadly rounded, more than twice as wide between eyes as median length.

Color.—Dull sordid green to greenish gray. Vertex with a broad waved black band just above margin and a similar broad waved band just below the margin. The pale marginal band just as wide as included ocelli. A broad tawny blotch just back of upper marginal line and between ocelli. Elytra grayish hyaline, nervures paler.

Genitalia.—Female last ventral segment with posterior margin strongly roundedly produced with a pair of long slender parallel processes at middle produced more than one-third the length of the segment, separated approximately the width of the ovipositor by a deep U-shaped notch. Male plates elongate, triangular, with long slender, tapered apices. Styles long, slender with apex curved inwardly. Aedeagus bifid at base with a curved dorsal portion bluntly rounded at apex and a pair of sharply pointed ventral processes which arise at apex.

Holotype male from Ramsey Canyon, Hauchuca Mountains, Arizona, September 17, 1935 (F. H. Parker); allotype female, Mexico City, Mexico, September 1, 1940 (DeLong); paratype male, Mexico City, Mexico, September 1, 1939 (C. C. Plummer). The latter specimens were swept from shrubs at an altitude of 9,000 feet.

Knullana plummeri n. sp.

Resembling *hauchuca* in form and appearance, but with distinct male genitalia. Length, male, 7 mm.; female, 7.5–8 mm.

Vertex broadly rounded, more than twice as wide between eyes as median length.

Color.—Dull green washed with yellow. Vertex with a black waved marginal line above and below ocelli. Anterior half of vertex tawny, posterior portion yellowish. Elytra dull greenish, veins yellow.

Genitalia.—Female last ventral segment produced, forming a pair of long slender parallel processes at apex which are separated by a U-shaped notch. Male plates long, triangular, with attenuate produced apices. Style elongate with a broad apex pointed on outer margin and with a slight inwardly produced tooth on inner margin. Aedeagus bifid at base with a short central dorsal process and a pair of broad plates from which arise on each side a long heavy spine which is curved upward at about half its length and tapered to a sharp point at apex.

Holotype male, allotype female and male and female paratypes collected at Cuernavaca (Morelos), Mexico, September 8, 1939, by C. C. Plummer and the author. These were swept from shrubs at the margin of pasture land. I take pleasure in dedicating this species to Dr. Plummer whose collecting in Mexico has revealed many interesting species of Homoptera.

STUDIES IN HUMAN INHERITANCE XX. FOUR SETS OF ALLELES TESTED FOR INCOMPLETE SEX LINKAGE

LAURENCE H. SNYDER,
The Ohio State University

It has long been known that in certain organisms some sex-linked genes are restricted to the X chromosome, others to the Y chromosome, while still others are found both in X and Y chromosomes, with consequent crossing over. In these organisms (e. g., certain fishes) there are thus three kinds of sex linkage: ordinary sex linkage (X chromosome factors), Y chromosome inheritance, and incomplete or partial sex linkage (factors on both X and Y).

Ordinary sex linkage and Y chromosome inheritance have long been known in man. Some thirty genes are known to be sex linked in the ordinary way, and four or five genes are known to be restricted to the Y chromosome. The latter include the genes for one type of webbed toes, icthyosis hystrix gravior, dense black hair on the entire ear, and hard round projecting skin lesions.

Koller and Darlington (1934) demonstrated that the sex chromosomes of mammals might also be expected to carry genes which occur on both X and Y with crossing over, since chiasmata occur between homologous portions of these chromosomes. The sex chromosomes therefore are constituted as follows: one portion of the X is non-homologous, carrying ordinary sex linked genes; the rest is homologous with a corresponding portion of the Y, and these homologous portions may carry genes which would be incompletely sex-linked. The Y in addition carries a non-homologous portion, which bears the Y chromosome factors passed from a father to all his sons.

With this histological observation and the knowledge of the three kinds of sex linkage in fishes, it was but a step to the conscious search for incompletely sex-linked genes in man. Haldane (1936) made such a search, using recorded pedigrees, and found evidence for the partial sex-linked nature of six genes: total colorblindness, xeradoma pigmentosum, Oguchi's disease, recessive epidermolysis bullosa, and two kinds of retinitis pigmentosa (one recessive unassociated with deafness, the other dominant).

Incompletely sex-linked genes will behave as ordinary autosomal factors in pedigrees except for one thing: some sibships tend to yield too many affected males and normal females, while other sibships yield too many normal males and affected females. In the case of a dominant gene, the affected offspring of affected fathers will tend to be of the same sex as the paternal parent from whom the father received the gene. In the case of a recessive gene the situation is not so obvious, and the requisite statistical analysis is rather intricate.

Thus the partial sex-linked nature of a gene may easily be overlooked in the ordinary analysis of pedigrees. Older known genes must be reanalysed for the possibility of incomplete sex linkage, and all new genes as they are discovered must be subjected to such analysis. Since the gene frequency is usually low for mutant factors in man, crossing over can not be studied between any two genes, and the investigation must concern itself with crossing over between the gene and sex, or, more exactly, between the gene and the unpaired non-homologous portion of the X and Y chromosomes.

In the absence of three-generation pedigrees, incomplete sex linkage may be investigated in paired sib material, using 2 x 2 tables such as were suggested by Penrose (1935) for autosomal linkage. Having on hand in our laboratory the records of a number of paired sibs tested for blood group, blood type, taste deficiency to phenyl-thio-carbamide and taste deficiency to mercapto-benzo-selenazol, we have set up these data in contingency tables, using the character as one variable and sex as the other. (A paper on the autosomal recessive nature of the taste deficiency to mercapto-benzo-selenazol is now being prepared for publication.)

Chi square was determined by the formula

$$\chi^2 = \frac{n\,[\,(ad) - (bc)\,]^2}{(a + b)\,(c + d)\,(a + c)\,(b + d)}$$

where a = number of pairs alike in both characters,
b = number of pairs alike in one, unlike in the other,
c = number of pairs unlike in the one, alike in the other,
d = number of pairs unlike in both characters,
n = total number of pairs of sibs.

Tables I to VI, inclusive, present the data in the form of 2 by 2 contingency tests, with the chi square determinations, and the appropriate probabilities with one degree of freedom. It will be seen that in no case is there a significant deviation from proportionality. It can therefore be stated that the genes for the blood groups, the blood types, the taste deficiency to phenyl-thio-carbamide and the taste deficiency to mercapto-benzo-selenazol do not appear to be located on the homologous portions of the sex chromosomes. We are testing this possibility for other factors in man as rapidly as possible.

TABLE I

		Sex		
		Like	Unlike	
Agglutinogen A.....	Like	84	52	136
	Unlike	37	17	54
		121	69	190

$\chi^2 = .076$ P = .95 — .70

TABLE II

		Sex		
		Like	Unlike	
Agglutinogen B............	Like	104	62	166
	Unlike	17	7	24
		121	69	190

$\chi^2 = .061$ P = .95 — .70

TABLE III

		Sex		
		Like	Unlike	
Agglutinogen M............	Like	94	55	149
	Unlike	22	9	31
		116	64	180

$\chi^2 = .070$ P = .95 — .70

TABLE IV

		Sex		
		Like	Unlike	
Agglutinogen N............	Like	83	38	121
	Unlike	33	26	59
		116	64	180

$\chi^2 = 2.78$ P = .30 — .05

TABLE V

		Sex		
		Like	Unlike	
Taste P. T. C..............	Like	93	63	156
	Unlike	42	29	71
		135	92	227

$\chi^2 = .004$ P = .99

TABLE VI

		Sex		
		Like	Unlike	
Taste M. B. S..............	Like	49	44	93
	Unlike	10	15	25
		59	59	118

$\chi^2 = 1.269$ P = .30 — .05

REFERENCES

Haldane, J. B. S. 1936. Annals of Eugenics, 7: 28–57.

Koller, P. C. and **Darlington, C. D.** 1934. Jour. of Genetics, 29: 159–173.

Penrose, L. S. 1935. Annals of Eugenics, 6: 133–138.

THE DISTRIBUTION OF CAMBARUS SLOANI BUNDY, IN OHIO[1]

RENDELL RHOADES,
Wilmington College,
Wilmington, Ohio[2]

The suggestion that *Cambarus sloani* might be found in southwestern Ohio was made in a letter from Dr. Edwin P. Creaser in 1937. Acting upon his suggestion, I began to look for this species and in September, 1938, *C. sloani* was taken in Shakers Creek, Warren County, Ohio. Further collecting westward and across the Great Miami proved the species to be common and often dominant in six counties.

SUMMARY OF DISTRIBUTION

C. sloani, now recorded for the first time from Ohio, is found in the southwestern corner of the state, west of the Great Miami and the Stillwater rivers, and south of the tributaries of Greenville Creek. The species has successfully crossed the Great Miami River in Warren and Hamilton counties and now occupies a few tributary streams to the east (Fig. 7). At the mouth of Clear Creek, Warren County, only a half mile east of the Great Miami, two specimens were taken with fifty *C. rusticus*. A small percentage of the crayfish populations in Taylors and Jordan creeks, Hamilton County, is composed of *C. sloani*. It was taken once in the Stillwater River system (two specimens in Dry Run, Madison Township, Montgomery County), but was not collected in Greenville Creek or its tributaries.

C. sloani has probably invaded Ohio from the Whitewater River system in Indiana, presumably in Darke and Preble counties where the headwaters of Seven Mile and Prices creeks closely approach the Whitewater system in the flat land;

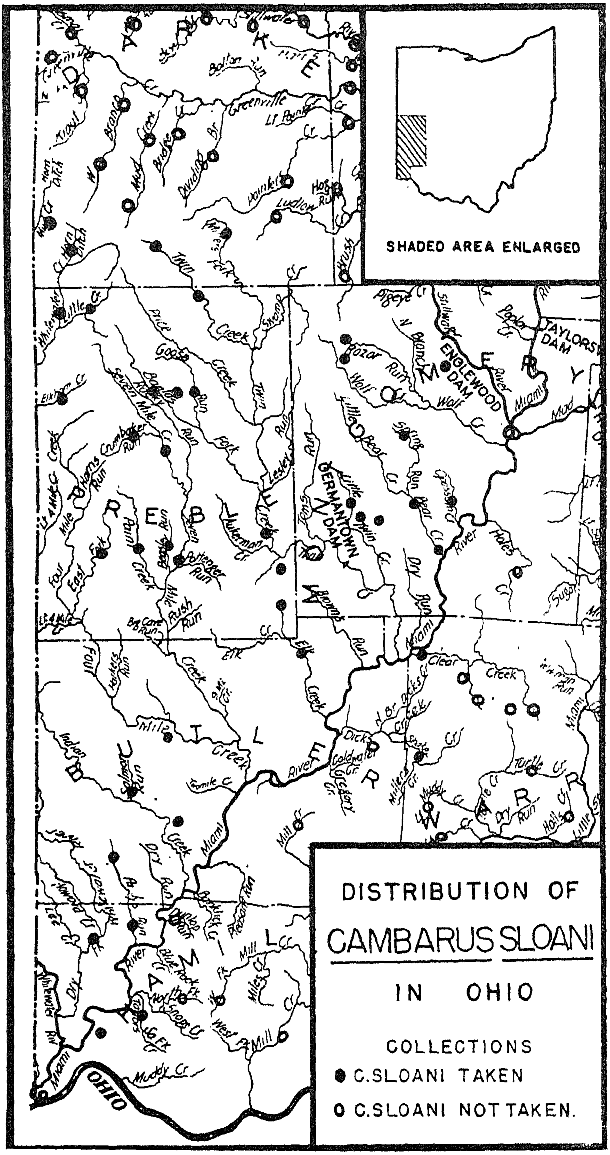
---

[1] This paper was prepared under the direction of Dr. R. C. Osburn, Department of Zoology and Entomology, Ohio State University, and with the co-operation of the Division of Conservation and Natural Resources.

[2] Acknowledgment is due Dr. Fenner A. Chace, Jr., Assistant Curator of Marine Invertebrates, Museum of Comparative Zoology, who furnished identified material of this species for comparison: New Albany, Indiana. (Bundy, type locality.)

I am indebted to Mr. Milton B. Trautman, Research Biologist, Ohio Division of Conservation and Natural Resources, who has so graciously found time among his own studies to assist and advise.

once the swamp forest of those counties. Seven Mile and Twin creeks contain the greatest concentration of this species in Ohio. Curiously, none were found in Indian and Four Mile creeks, except in a few small tributaries.



No specimens have been taken from the Great Miami River itself. This river seems to be an unfavorable ecological system, even to the extent of retarding the spread of the species eastward. In recent years pollution may have become a barrier.

A specimen was taken in Shakers Creek, Warren County, a locality near the old Lebanon Canal bed. In this vicinity the Great Miami and the Little Miami drainage areas were connected from 1835 to 1865 by "Old Shakers Pond." *C. sloani* has not been taken in the Little Miami River drainage area. However, Little Muddy Creek would seem the most probable locality.

The species is known from Southern Indiana and recorded from "northern Kentucky" by Bundy. The distribution of *C. sloani* has not been well studied in Indiana. In that state it is known from the Whitewater, the White, the Muscatatuck, and the Blue rivers, all streams of southern and eastern Indiana. From the type locality at New Albany, Floyd County, Indiana, Dr. J. Sloan reports that this species is a burrower in banks of streams (Faxon, '85: 90). No burrowing habit has been observed in southwestern Ohio, except that shallow pockets have been cleaned out under flat stones.

Streams inhabited by *C. sloani* generally have a flat stone bottom. The stones are broken and well rounded by the action of the water. A lack of such stones may explain the absence of the species in Indian and Four Mile creeks, which also lack the stability of bank and bottom present in Twin Creek and Seven Mile Creek. *C. sloani* is most often found near algal beds and aquatic vegetation, and in aquaria the species consumes large quantities of plant material. Temperature does not seem to be an important factor in its distribution.

TAXONOMIC REMARKS

C. sloani belongs to the *Cambarus limosus* group, probably the most primitive division of the subgenus *Faxonius*. The male of this group is characterized by short thick gonopods, which are split for only a short distance from the tip. The annulus ventralis of the female is little sculptured and usually low and flat.

Characters.—Rostrum long with straight, slightly converging sides; excavation moderate with margins not thickened. Sides of acumen concave, forming, with the sides of the rostrum, sharp angles or small horny tips; rarely spines in adult. Spines normal in juvenile specimens. Broad, short median carina in rostrum. Postorbital ridges prominent but ends never spiniform. Cervical groove slightly sinuate and broken above the more or less developed acute lateral spines. Areola wide (3 to 5 rows of dots). Carapace subquadrangular with no unusual granulations, but many closely set large dots (Fig. 2).

Antennal scale long, and broadest at or above the middle; medial margin uniformly curved. Epistoma broadly triangular with the two free edges elevated, elevation at the anterior tip bearing a small emargination.

Chelae with outer margin of hand keeled. Keel often divided by a closely set row of dots, forming almost a solid line down the margin. Two well developed rows of depressed tubercles on the inner margin of the palm, and usually a few irregular tubercles appear above these in old individuals. The medial margin of the movable finger also bears two rows of the same type of rounded tubercles, which diminish in size toward the distal end of the finger.

Form I.—Copulatory appendages of first abdominal segment short and thick, reaching to the coxopodite of the second or third walking leg. Hay ('95: 495) describes the rami with the outer tip turning out and the inner tip turning in. This is found to be true from a ventral aspect, that is, the outer tip curves laterally and the inner tip curves medially, but from side view the outer tip is straight and the inner tip is curved strongly outward. Outer ramus twice as thick as inner one and straight or only slightly recurved from lateral view. Body of appendage heaviest at or below the middle. Tufts of hair found on the base of the internal surface of the inner ramus and on the medio-ventral ridge near the basal articulation (Figs. 4 and 6).

Form II.—Copulatory appendages slightly shorter than Form I, and lacking the horny tip on the outer ramus. Instead, this part is bluntly rounded at the tip and has a uniform diameter throughout the distal half, which is increased twice in the basal portion. Internal ramus thicker and more closely joined to the external portion. The long gentle curvature of the inner ramus in Form II contrasts with the strong curvature near the tip in Form I. Thickest part of appendage at or above the middle. Tufts of hair ventrally and near the base may or may not be present (Figs. 1 and 3).

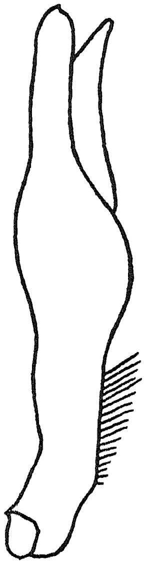
The annulus ventralis of the female as figured and described by Hay ('95: 496) seems to be inadequate for Ohio specimens. He does not mention the prominent diverging ridges along the anterior border nor does he refer to the deep furrows which they overhang. The elevated posterior border is a common character in the Ohio and Indiana specimens, but the tuberculation on the posterior rim amounts to no more than a general high area, as shown by my specimens (Fig. 5). This

---

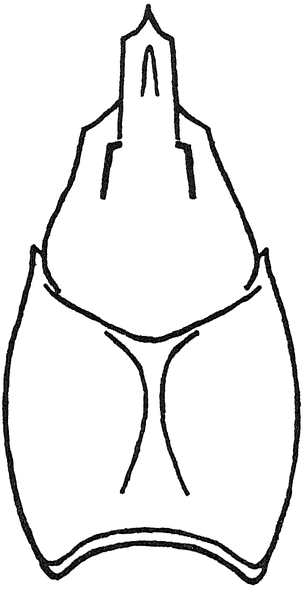
EXPLANATION OF PLATE

Cambarus sloani

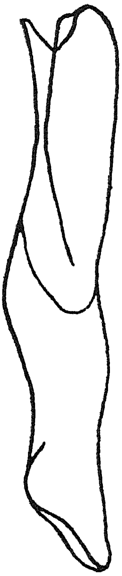
Fig. 1. Gonopod, Male II, outer view.
Fig. 2. Carapace, dorsal view.
Fig. 3. Gonopod, Male II, inner view.
Fig. 4. Gonopod, Male I, outer view.
Fig. 5. Annulus ventralis
Fig. 6. Gonopod, Male I, inner view.
Fig. 7. Distribution of *Cambarus sloani*.



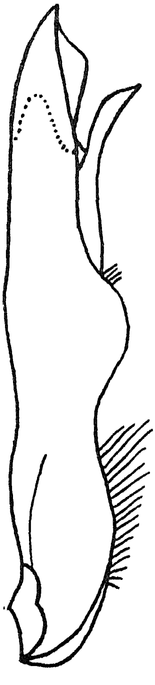
1



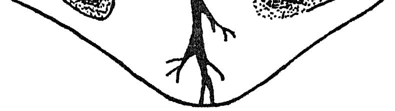
2



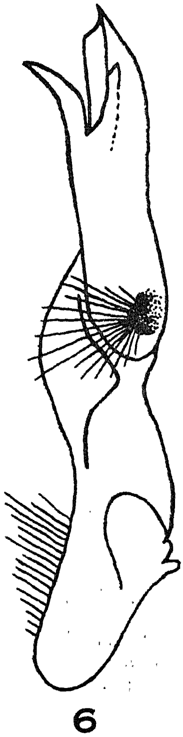
3



4



5



6

posterior area is often cut by a deep medial furrow which extends anteriorly and bends to the observer's left, and is the posterior border of a prominent tubercle near the middle of the depressed area. The anterior border, nicely described by Bundy and Hay, is depressed below the sternal plates, which slope strongly downward to join the annulus.

Bundy ('76: 24) states that the "first abdominal legs short, bifid, outer part slightly longer, flattened, bent outward at apex, slightly recurved, acute; tubercles at inner base small." This describes Form I, especially from ventral view. He states that the third maxillipeds are smooth below, hairy within.

The basal segment of the telson is bispinous, according to his description, but this is not a specific character since many other species possess such spines.

Hay ('95: 496) describes the copulatory appendages as having "large inwardly projecting knobs at the base of the appendages." This projection, as Bundy states, is smaller in Form II than in Form I. The appendages in Form II often lack any basal articulation and are thus easily lost.

COLORATION OF CAMBRIUS SLOANI

The color resembles somewhat the members of the *propinquus* group. The green pigment, so prevalent in the *rusticus* group, is lacking. The coloration of the carapace is in shades of brown. The darkest color is found immediately in front of the cervical groove, and on the dorsolateral portion of the posterior branchial regions. The middle of the areola often bears a dark stripe of brown. Within the concavity of the rostrum is always found light and dark brown in various patterns.

The abdomen of old individuals is marked with two irregular lines of dark pigment down the dorsum; in young specimens these may appear as a dark spot on each segment. The posterior margin of each segment is marked with a thin line of orange, extending over the tergum from one pleural lobe to the other.

The chelae are light flecked with dark, which at first sight, gives them the appearance of having coarse tuberculation. The tubercles on the dorsal anterior articulation of the carpus, the dorsal articulation of the movable finger, and the tips of both fingers are bright orange. Immediately behind the orange tips of the fingers are brownish, almost black bands.

The ventral portions of the body of clean individuals are nearly white, much lighter than any of the *rusticus* or *propinquus* group.

COPULATION RECORD

Oppossum Run, Sec. 23, Jefferson Twp., Montgomery Co., Ohio. October 10, 1938.

REFERENCES

Bundy, W. F. 1876. Bull. Ill. Mus. Nat. Hist., 1: 24.
1877. Proc. Acad. Nat. Sci., Phila., 1877, p. 172.
Faxon, W. 1885. Mem. Mus. Comp. Zool., 10 (4): 89–90.
Hay, W. P. 1895. 20th Ann. Rept. Ind. Geol. & Nat. Resources Sur., 1895, pp. 195–6.

A SYSTEMATIC STUDY OF THE MAIN ARTERIES IN THE REGION OF THE HEART—AVES

II. (Crotophaga ani), (Saurothera merlini), and (Coccyzus americanus)

FRED H. GLENNY,
Department of Biology,
Western Reserve University

INTRODUCTION

In a recent paper (2), the writer discussed the arrangement of the arteries in the region of the heart of three members of the Heronidae and the Belted Kingfisher (*Ceryle alcyon*). A recent shipment of birds from the West Indies made possible the study of the arrangement of these same arteries in three members of the Cuculidae. The findings are set forth in the following observations.

OBSERVATIONS

The right and left common carotid arteries arise from the innominate arteries and proceed anteriorly to the thyroid gland. At this point each vessel gives rise to (1) an internal carotid artery which passes anteriorly along the side of the neck, and (2) an external carotid artery which soon enters the hypapophysial canal. The internal carotid is superficial and smaller than the complimentary external carotid artery. The external carotids of the Cuculidae do not fuse to form a common trunk artery as in the case of the Kingfisher.

The subclavian artery sends off the axillary artery and the internal mammary artery before giving rise to the two pectoral arteries. The internal mammary arises as a branch of the coracoid artery (new artery) which supplies the muscles in the region of the coracoid bone. In general this is the condition represented in most species of Ohio birds, and is found especially common in the Passeriformes.

As in other birds, the right 4th aortic arch arises from the right innominate artery and passes posteriorly to fuse with the right radix aorta which later joins the dorsal aorta. In both Saurothera and Coccyzus, the left radix aorta is present as a ligamentous vestige, but in Crotophaga there is a small stump of the right radix aorta with a small ligamentous tip.

In the latter, the anterior projection of the ligament is entirely wanting.

A vestige of the embryonic right 6th aortic arch is present as the Ligamentum Botalli (3) in each of the three species. This ligament is located on the ventral surface of the right radix aorta and is attached anteriorly to the pulmonary artery. The extent of this ligament varies slightly, and is most prominent in Crotophaga, somewhat reduced in Saurothera, and almost imperceptible in *Coccyzus americanus*. With reduction of the left radix aorta, the left 6th arch becomes completely absorbed and cannot be traced in the adult specimens.

CONCLUSIONS

It may be concluded that the Cuculidae show considerable similarity in the basic arrangement of the main arteries in the region of the heart. This similarity within the family may aid in the superordination of the families in the order.

Since the Kingfisher (*Cerlye alcyon*) (1 and 2) shows a more primitive condition than that found in the Cuculidae, it may be regarded by some as more primitive, but the writer must conclude that there are several points of advancement expressed in the basic arrangement over that of the Cuculidae (2), and that the retention of the left radix aorta is to be regarded as singular and characteristic of the species.

SUMMARY

1. The main arteries in the region of the heart of three species of Cuckoos were completed. The arrangement of these vessels were strikingly similar in all species.
2. The ligamentous vestige of the left radix aorta was present in each species.
3. The right Ligamentum Botalli was present in each species, but the left vestige of the 6th arch was completely atrophied.

LITERATURE CITED

(1) **Glenny, Fred H.** 1939. "An Anomalous Artery in the Kingfisher (*Ceryle alcyon*)." Columbus. The Ohio Journal of Science, 39: 94–96.

(2) **Glenny, Fred H.** 1940. "A Systematic Study of the Main Arteries in the Region of the Heart—Aves, Part I." Philadelphia, Anatomical Record, 76: 371–380.

(3) **Glenny, Fred H.** 1940. "Presence of the Ligamentum Botalli in the Golden Eagle (*Aquila chrysaëtos*) L., the Red-tailed Hawk (*Buteo borealis borealis*) Gmelin, and the common Pigeon (*Columba livia*)L." Columbus. Ohio Journal of Science, 41: 46–49.

BOOK NOTICES

The Modern Study of Botany

The "Textbook of Botany" by Transeau, Sampson, and Tiffany is not just another text, but a book full of interesting reading, a text which combines the "fundamentals" with the realities of life. One finds in it the usual material contained in most college texts, but the arrangement is new, the approach is alive. The book is remarkably well illustrated, with numerous attractive halftones and several reproductions of kodachrome pictures, as well as the usual line drawings. An examination of the 424 figures (with their legends) gives a comprehensive view of the contents.

Wherever possible, the approach is physiological or ecological, as is to be expected from these authors. The arrangement of topics is pleasing; one thing leads logically to the next. Although the essential sequence is here, the book is not conspicuously divided, as are so many texts, into a part primarily structure and physiology, followed by a part primarily morphology of the several phyla. In fact, about two-thirds of the book is devoted to carefully inter-related treatments of physiology and anatomy together with the influences of environment and heredity. For example, "the tissue system of leaves" is followed by "environment and leaf development,'. and "hereditary differences in leaves." "A bit of useful chemistry" should be really useful before embarking upon the several chapters concerned with food manufacture. A general treatment of "non-green plants" is followed by chapters on the "biology of bacteria," "bacteria of the soil," and "fungi," with a chapter on "plant diseases" in which the student discovers the role of bacteria and fungi in causing diseases of higher plants. "Under-water environments" is a pleasing prelude to the consideration of "algae." A brief but profusely illustrated chapter on the vegetation of North America gives a clear picture of the major plant formations.

It is true that this text is not adapted to the usual routine followed in many colleges, but the "routine" could be adapted to the text. The use of such a text should help to revitalize college botany.—*E. L. Braun.*

A Textbook of Botany, by E. N. Transeau, H. C. Sampson, and L. H. Tiffany. 812 pages. New York, Harper and Brothers, 1940. $4.00.

This Living World

One of the major objectives, if not the chief objective of the general course in biological science taught in many colleges, is to aid the student in acquiring a more accurate concept of living organisms and his own relation to the world of life. The paths which are followed in attempting to achieve this objective are almost as numerous as the men and women who teach such courses. No "best" procedure has yet been developed, nor probably ever shall be. Each teacher strives constantly to find a "better" plan and out of these strivings new books develop which are submitted for the approval and use of others.

Another admirable attempt at a *better way* is presented in the present volume. This book is designed for use with a companion volume, "This Physical World," in "cultural" or "exploratory" type courses. The book reads like a novel. The scene is set with a word picture of the changing concepts of life, the nature of the earth's crust, and the turbulant domain which life inhabits. From this point the plot is developed first in a general way with consideration of "living chemicals," "patterns of life," life in the seas, and life on the land. Then more particularly with reference to man; his racial development, his similarity to other vertebrates, his physiology and finally a short discussion of human culture.

Such a book is not intended for use as a text in the usual laboratory course in Zoology, but it surely could be used with profit as supplementary reading. At the end of each chapter is a list of references for more extended reading, each of which is annotated.

The mechanics of the book are excellent. The heavy black type is restful to the eye. The illustrations are superb. Many of these are Louise Waller Germann's black and white semi-diagrams resembling wood cuts. Others are actual photographs which show an expert's touch.—*Paul E. Schaefer.*

This Living World, by C. C. Clark and R. H. Hall. 519 pages. New York, McGraw-Hill Book Company, Inc. 1940. $3.25.

A New Bird Guide

This little book is intended to give the bird student a simple but adequate pocket guide for the identification of birds in the field. About half the book consists of an analytical key, and the rest of illustrations and descriptions.

The characters given in the key are for the most part adequate for field identification. The first divisions of the key are based on habitat. Although many species are keyed out in two or three of the six different habitat groupings, the student may occasionally have to look for a bird under a somewhat different habitat in the key than that in which he sees the bird. The surface-feeding ducks, for example, are keyed out in only one habitat grouping, "marshes, reeds, wet meadows," and not in "open water: lakes, ponds, streams."

The illustrations are by Roger T. Peterson, and depict 184 species in 27 line drawings, 4 colored plates, and 14 monochrome plates. They are similar to those in Peterson's "Field Guide to the Birds." The descriptions are brief and concise, and include information on the size, field markings, residential status in northern Ohio, and habitat. No attempt is made to designate or distinguish between subspecies.

The book covers the more common birds of the Lake Erie region, but will be usable for the more common birds throughout northeastern United States. It keys out 188 species (including different plumage variations) and contains descriptions of these and some 30 others. While nearly every bird which a student might see in northern Ohio is included, there are some, which are rare in northern Ohio but more common in central or southern Ohio, which are omitted. For example, the Carolina chickadee, Bewick's wren, summer tanager, prairie warbler, and a number of others are not mentioned.

This guide is pocket size and is printed on a good grade of paper and bound with a flexible binding. It should prove particularly helpful to the beginning bird student, but even experienced bird students will find it a good book to own.—*D. J. Borror.*

A Field Key to Our Common Birds, by Irene T. Rorimer. 160 pp. Cleveland Museum of Natural History, Pocket Natural History No. 8. 1940. $1.50.

Physico-Chemical Methods

Reilly and Rae

The third edition of this well known and authoritative work is presented in two volumes and the authors intend to later add a supplementary volume before bringing out a fourth edition. Volume I, *Measurement and Manipulation*, is concerned chiefly with the principal types of measurement and essential apparatus. The inclusion of a new chapter on Measures and Units written by Professor A. O'Rahilly of University College, Cork, should prove of great value to both students and teachers of Physical Chemistry laboratory courses.

Volume II, *Practical Measurements*, deals mainly with practical applications, covering such topics as separation processes, optical measurements, spectrometry, electrochemistry, indicators, hydrogen in concentration and electrolytic conductivity. Included also are new chapters on Colloids and Radioactivity together with a revised and rewritten chapter on Thermionic Vacuum tubes.

A new and worthwhile feature of the present edition is the inclusion of literature references covering each section under the heading of "Suggestions for Further Reading." While the authors have succeeded in the difficult task of preventing the work from assuming encyclopedic proportions, it does seem that some of the more elementary material could still further be curtailed or eliminated, so as to provide a more extended treatment of the advanced physical-chemical methods, all contained in a single volume.—*Wesley G. France.*

Physico-Chemical Methods: Joseph Reilly and William Norman Rae. Volume I, *Measurement and Manipulation*, 686 pp. Volume II, *Practical Measurements*, 580 pp. D. Van Nostrand Co., Inc. December, 1939. Price, $17.50.

THE OHIO JOURNAL OF SCIENCE

VOL. XLI MAY, 1941 No. 3

THE FIFTIETH ANNIVERSARY

OF THE

OHIO ACADEMY OF SCIENCE

The Publications Committee of the Fiftieth Anniversary Celebration of the Ohio Academy of Science takes pleasure in presenting herewith the invitational addresses which were delivered before the Academy in Columbus during May, 1940, in connection with the golden anniversary. Twenty-eight papers were presented on that occasion, of which eighteen are published here. The remaining ten, because of previous commitments or for other reasons, are not to be published. It is hoped to be able to present in a later issue of the JOURNAL some of the historical data which were assembled for the occasion of the anniversary.

TABLE OF CONTENTS

PAGE

Presidential Address—A Present Day Examination of the Postulates of John Dalton................*Wm. Lloyd Evans* 105

Research on the Central Auditory Mechanisms: Some Recent Methods and Results..........................*E. A. Culler* 117

Some Social Aspects of Deafness................*E. R. Abernathy* 123

The Development of High Voltage for the Production of Neutrons and Artificial Radioactivity....*E. U. Condon, Ph.D.* 131

A Comparative Study of Neutron- and X-Radiation upon Biological Tissues in the Cancer Problem...*Isadore Lampe, M.D.* 135

Cancer: Clinical and Experimental Aspects, *Francis Carter Wood, M.D.* 139

The Classification of Nerve Fibers.............*Herbert S. Gasser* 145

The Interaction of Neurones......................*R. W. Gerard* 160

Encephalization of Motor Functions During the Evolution of the Primate Nervous System.................*J. F. Fulton, M.D.* 173

A Scaled Model of a Proposed Protein Structure, *Edward Mack, Jr.* 183

Ecological Factors and Drosophila Speciation..*Warren P. Spencer* 190

The Origin of Ohio Soils.......................*Guy W. Conrey* 201

Prehistoric Factors in the Development of the Vegetation of Ohio.............................*Edgar Nelson Transeau* 207

The Aerial Traverse. An Application of Aerial Photography to Geographic Studies........................*John L. Rich* 212

Postglacial Vegetation in the Erie-Ohio Area.......*Paul B. Sears* 225

The Differentiation of the Deciduous Forest of the Eastern United States.............................*E. Lucy Braun* 235

Recent Trends in Horticultural Research..........*J. H. Gourley* 242

Professor John Henry Schaffner...............*Adolph E. Waller* 253

Book Notices..........134, 138, 144, 159, 172, 200, 206, 211, 241, 250

PRESIDENTIAL ADDRESS

A PRESENT DAY EXAMINATION OF THE POSTULATES OF JOHN DALTON

WM. LLOYD EVANS,
The Ohio State University

The constitution of the Ohio Academy of Science prescribes that on this occasion its President shall deliver an address. As much as I should like to confine my remarks to a discussion of some recent advances in the chemistry of the carbohydrates—an area of organic chemistry in which I find my greatest research satisfactions—a discussion of this special field of work on this occasion would have but a limited interest. However, there is one topic in which I am bold enough to believe that all members of the Academy have genuine interest. I refer to John Dalton's atomic theory of matter.

The concept of the discrete nature of matter has been one of the central themes of the science of chemistry since the first decade of the nineteenth century. In the middle nineties, the physicist became busily engaged with his brother chemist in a study of the nature of this small unit, in fact, a large share of his research endeavor is now directed toward the solution of this very fundamental problem. With the time at my disposal I shall attempt to make a brief examination of the postulates of John Dalton in the light of present day knowledge.

The atomic concept of matter finds its roots in philosophical thought that comes to us from remote antiquity. In an ancient Chinese document (Shoo King) it is conjectured that there are five elements, namely, water, fire, wood, metal, and earth. These elements were probably regarded as the materials from which all natural substances were derived, in quite the same way as we read today that the newly synthesized silk, nylon, can be made from air, water, and coal, which is true, but the actual process is a long journey. In the distant past, Kanada, the East Indian philosopher, gave utterance to the following opinion: "the mote which is seen in a sunbeam is the smallest perceptible quantity. Being a substance and an effect, it must be composed of what is less than itself. This again must be composed of what is smaller, and that smaller thing is an atom."

In the four or five centuries preceding the time of Christ, the Grecian philosophers gave much thought to this general problem. Leucippus (circa 500 B. C.) believed that all material substances were made up of atoms and empty spaces. His distinguished pupil, Democritus, reasoned as follows: "If every substance is divisible to infinity, and the division is never arrested, we come to one or two conclusions—*either nothing remains or something is always left.* From this reasoning he concluded that it was necessary to assume the existence of real, indivisible units of matter. This group of philosophers called themselves Atomists. Another school of Grecian philosophers under the influence of Aristotle maintained that matter was continuous and filled all space, a point of view that has had its adherents until relatively recent times.

The outstanding contribution in the pre-Christian era was the epic poem of Lucretius, "De Rerum Natura." In this poem Lucretius showed himself to be an ardent adherent of the atomic concept of matter, and by means of it he foreshadowed some of the fundamental notions underlying modern physics and chemistry. May I quote but one suggestive passage:

> "Infinite atoms in a boundless world,
> By endless motion build the frame of things."
> —Bk. I, 63, Johnson translation.

This and other examples of early philosophical inquiry should command our deepest admiration by reason of the general correctness of the views expressed concerning the nature of matter. Had the experimental method of verification of such ideas been in vogue at that time it is safe to assert that our present state of knowledge concerning Nature would have been much more advanced than it is at the present time.

Many important experimental discoveries were made in the latter decades of the 18th Century. From the laboratories of those fruitful years of scientific work came certain fundamental laws bearing upon the quantitative character of chemical reactions. We are indebted to Richter, the German, for the Law of Inter-proportionality, to Proust, the Frenchman, for the Law of Definite Composition, and to John Dalton, the Englishman, for the Law of Multiple Proportion. In an attempt to find a satisfying explanation for the quantitative relationships set forth in these three generalizations and that concerning the indestructibility of matter, John Dalton formulated the postulates which constitute his now well known atomic theory. The postulates of this important doctrine were these:

1. All bodies of sensible magnitude are constituted of a vast number of extremely small particles or atoms of matter bound together by a force of attraction which, as it endeavors to prevent their separation, is called attraction of cohesion; but as it collects them from a dispersed state is called attraction of aggregation or more simply affinity.
2. The ultimate particles of all homogeneous bodies are perfectly alike in weight, figure, etc. In other words, every particle of water is like every other particle of water; every particle of hydrogen is like every other particle of hydrogen, etc.
3. No new creation or destruction of matter is within the reach of chemical agency. All the elements we can produce consist in separating particles that are in a state of cohesion or combination and joining those that were previously at a distance.
4. The ultimate particles of all simple bodies are atoms incapable of further division. These atoms (at least viewed along with their atmospheres of heat) are all spheres and are possessed of particular weights which may be denoted by number.
5. If there are two bodies which are disposed to combine, then their combination takes place by atoms.
6. In an elastic gas each particle occupies the center of a comparatively large sphere and supports its dignity by keeping all the rest, which by their gravity or otherwise are disposed to encroach upon it, at a respectful distance.

In a discussion of these postulates it must be remembered that they were formulated in the earlier years of a period in which the answer to questions concerning man's physical surroundings were being sought by the laboratory method—a procedure that was destined to exercise a profound influence on the development of our civilization. In the first postulate Dalton was merely saying that all available quantitative experimental data concerning chemical reactions acquired fundamental significance if it were assumed that "all bodies of sensible magnitude are constituted of a vast number of extremely small particles or atoms," that is, matter behaves experimentally *as though* it were atomic, or granular in nature, as contrasted with the point of view that it is continuous in structure.

In support of this assertion the sciences of chemistry and physics of today furnish convincing experimental evidence. The laboratory records of chemistry reveal the existence of over a half million compounds, the vast majority of which have been synthesized by processes in which the existence of atoms was taken for granted. In no case do we find a departure in the composition of these compounds from that which could have been easily predicted, i. e., in no case do we find an exception to the laws of chemical combination upon which Dalton erected his theory. Throughout the world, the chemist, more especially the organic chemist, is constantly preparing pure compounds hitherto unknown. The foundation upon which the chemist's great success rests is the very spirit of that portion of postulate one which assumes the existence of atoms.

In the field of physics we find equally convincing laboratory evidence in support of the Daltonian doctrine with reference to the discrete nature of matter. I have chosen as illustrations the experimental determination of Avogadro's number (6.06×10^{23}), a physical constant which gives the number of molecules present in a gram molecular weight of any pure substance.

Jean Perrin, Professor of Physical Chemistry at the Sorbonne, found, in his classical study of the Brownian movement, that the value of Avogadro's Number was 6.82×10^{23} molecules. From a calculation based on the ratio of the mass to the electrical charge of the hydrogen ion, the value of this constant has been found to be 6.06×10^{23}, a value confirmed by Langmuir with his oil film technique. Again, on the basis of the volume of helium ion emitted from radium in one day, and also the number of such particles given off in one second, Rutherford and Boltwood calculated the value of this constant to be 6.16×10^{23}. Here we have four separate and entirely distinct methods of experimental approach to the determination of this important constant that yield data that are sufficiently in accord with one another to justify the spirit of postulate one, which to repeat assumes that matter is granular in its nature. Furthermore, it should be pointed out that the Avogadro Constant and the gram-molecular weight permit us to calculate the *actual* weight of any molecule, and from the result so obtained in the case of hydrogen we can determine the actual weight of an *atom* and that of the *electron*. The actual weight of the hydrogen atom was thus found to be 1.64×10^{-24} grams.

It may be added that were he living today Dalton would undoubtedly admit with the utmost satisfaction that 6.06×10^{23} molecules and

1.64×10^{-24} were numbers sufficiently large and sufficiently small respectively to justify and confirm his use of the phrase "a vast number of extremely small particles". Thus, it becomes evident that the modern physical sciences furnish what seems to be conclusive experimental data which justify the assumption of Dalton that matter is atomic in structure.

Since Dalton belonged to that group of natural philosophers who believed in the discontinuity of matter it was only natural for him to make the assumption in postulate four that "the ultimate particles of all simple bodies are incapable of further division—and are possessed of particular weights which may be denoted by number." What have our modern activities to say with reference to these assertions?

Concerning atoms having characteristic weight it should be noted that in 1905 John Dalton published the first atomic weight table. Among some of its features of interest to the chemist are these:

1. Hydrogen was used as a standard of comparison, and was assigned the value of 1, a procedure followed until relatively recent times. 2. An examination of the table shows that Dalton used the term "atom" to designate the smallest particle of both the present day element as well as the present day compound. 3. He arrived at the value for water, namely, 6.5, by adding his atomic weights of hydrogen and oxygen. The translation of these values into modern chemical symbols and formulas would give HO as the formula for water, i. e., one atom of each element. 4. Out of this table of atomic weights and the more accurate ones which followed it emerged a distinct effort to correlate these characteristic weights of the elements and their chemical properties. This is clearly shown in the publication of Doebereiner's idea of triad groups of elements in 1817, Newlands Law of Octaves in 1864, and the concept of periodicity amongst the properties of the elements as announced by Lothar Meyer in 1864 and by Mendeleeff in 1869.

In the eighteen-nineties, some ninety years after Dalton postulated that "the ultimate particles of all simple bodies are incapable of further division," three very important and apparently non-related discoveries were made. I refer to the discovery of radio activity and the element radium by Bequerel and the Curies, respectively; the discovery of the noble gases of the atmosphere by Ramsay and Rayleigh; and the discovery of X-rays by Roentgen. Today we know that these epoch making events are inextricably interwoven when they are considered in connection with the problem under discussion. We need only to be reminded that radium, thorium, and uranium are elements undergoing decomposition with an attendant evolution of three different rays, the alpha rays, or the He^{++}, beta-rays or the electrons, and the gamma rays, or X-rays of a very high frequency. The final product in each case was found to be the element, lead. Here then were atoms of certain known elements giving birth to the helium ion (He^{++}) an element of lower atomic weight, and to the age long known element, lead, truly a new kind of alchemy, and a case where elements were undergoing "further division" but not into like particles.

In his efforts to obtain more intimate knowledge concerning the nature of the atom, the present day physicist has attempted to shatter the atom into small particles through a vigorous bombardment. His projectiles are the electron, the alpha particle, (or He^{++}), the proton, (or H^+), the recently discovered neutron, and deuteron, that is the ion of heavy hydrogen, (D^+). The heaviest piece of artillery is the modern cyclotron, an instrument which is capable of imparting a speed to these projectiles of the order of 9000–18000 miles per second with an energy of the order of 10,000,000 electron volts. Therefore, it is not a matter of great surprise that an occasional atom may be broken down into more simple particles when it is struck under these conditions.

Within recent months only the fission of uranium, the heaviest known atom, has been announced. This was accomplished by the bombardment of uranium with fast moving neutrons. Fourteen different elements were found in the atomic debris. (Ba, La, Ce, Kr, Rb, Sr, Y, Zr, Xe, Cs, Sb, Te, I, and Br.). By some authorities the fission of the uranium atom is regarded as the most important discovery of the year 1939, and it is also the greatest explosion in atomic history. With reference to that portion of postulate 4 which asserts that "the ultimate particles of all simple bodies are atoms incapable of further division," the modern physical sciences have shown that the fact of "further division" is a natural process as well as a laboratory one. However, this portion of the Daltonian doctrine which asserts that the atoms have characteristic weight which may be denoted by a number is in itself a great contribution to knowledge. It need only be remarked that all our analytical and synthetic processes in the field of chemistry whether they be academic or industrial rest upon these numbers which tell us the relative weight of each atom referred to some element chosen as a standard. Again we must not forget the stimulus which these numbers gave to a study of the possible relationship which might exist between these numbers and the chemical properties of their respective elements, thus leading to the discovery of the Periodic Law, which has pointed so unerringly to relationships and properties hitherto unperceived.

Again, we find Dalton referring to the property of weight in postulate two when he asserts that "The ultimate particles of all *homogeneous* bodies are perfectly alike in weight, figure, etc. In other words, every particle of water is like every other particle of water; every particle of hydrogen is like every other particle of hydrogen."

Some of the important present day facts bearing on the validity of postulate two are these: When the *atomic weights* of the specimens of lead obtained from the three radioactive sources mentioned above were determined by Theodore William Richards and others, a surprising fact came to light, namely, that the atomic weights of the lead obtained from these sources showed a variation from the classical value which was in excess of that due to experimental error. Here then we had experimental evidence for the existence of an element whose ultimate particles were not perfectly alike in weight. These atomic species of a given element are known today as isotopes, since a study of the various steps in the natural degradation of radium, thorium, and uranium show that these new kinds of lead atoms occupy the same position in the periodic arrangement of the elements. May we press this point further.

The discovery of deuterium, or heavy hydrogen, by Urey, Brickewedde and Murphy in 1932, was another event that had an important bearing on the views of Dalton with respect to the homogenity of atoms. The atomic weight of heavy hydrogen (2.0147) is approximately twice that of ordinary hydrogen. (1.0078). The density of heavy water at 25° (1.1076) is approximately 11% greater than that of ordinary water (0.99707) at the same temperature (25°). Heavy water boils at 101.4° C. and freezes at 3.77° C. Since Giaque and Johnston found that oxygen existed as three isotopes then it follows that it is possible to have nine different molecules of water. (These would have the following formulas: H_2O', H_2O'', H_2O''', D_2O', D_2O'', D_2O''', HDO', HDO'', and HDO'''). This number may be increased in the future through the discovery of other isotopes of either hydrogen or oxygen.

Although our postulate asserts that "every particle of water is like every other particle of water, and every particle of hydrogen is like every other particle of hydrogen," your attention is invited to a fine example of clear and careful thinking on the part of John Dalton with respect to this one point. I will quote from his book entitled "A New System of Chemical Philosophy" published in 1808, volume I, page 142: "whether the ultimate particles of a body, such as water, are all alike, that is, of the same figure, weight, etc., is a question of some importance. From what is known, we have no reason to apprehend a diversity in these particulars; if it does exist in water, it must equally exist in the elements constituting water, hydrogen and oxygen. If some of the particles of water were heavier than others, if a parcel of the liquid on any occasion were constituted principally of these heavier particles, it must be supposed to affect the gravity of the mass, a circumstance not known. Similar observations may be made on other substances." This paragraph is one which clearly foreshadows the possible existence of isotopic elements, and the new compounds that might be formed from them.

These data with reference to the discovery of isotopic elements immediately raise the query concerning the significance of the chemist's atomic weight. It may be said at once that the chemist's atomic weights are the *average* weight of all the isotopic atoms composing a given element. Since the isotopes of any given element are generally chemically indistinguishable it is necessary to use *physical* methods for the determination of their respective atomic weights and the relative amounts of each species present. One of the most notable procedures for this purpose is that known as positive ray analysis, a fruitful method of research with which the names of Thomson, Aston, Dempster and Bainbridge are intimately associated. By this method it has been found that the atomic weights of the individual species are practically whole numbers, a fact which awakens a renewed interest in Prout's hypothesis. A comparison of the chemist's atomic weight of magnesium (24.32) with that determined by positive ray analysis (24.375) shows a difference of only 22 parts in 10,000. This remarkable concordance obtained by procedures as remotely different in the fields of chemistry and physics bears eloquent testimony to the sound thinking of the investigators to whom we are indebted for these experimental data.

With reference to the use of the word homogeneous in this postulate, John Dalton probably had in mind what we ourselves believed concerning the nature of an element and a compound prior to the "isotopian age." What was thought to be homogeneous we now know to be heterogeneous when regarded from the standpoint of weight and the various implications of weight. It must be remembered that the atoms of a given isotope are homogeneous, but the atoms of the several isotopic species are heterogeneous.

At this point reference must be made to that part of postulate 2 which asserts that "the ultimate particles of all homogeneous bodies are perfectly alike in . . . figure," and to that part of postulate 4, which declares that "*the atoms* of all simple bodies are spheres." Obviously, these statements have reference to shape and structure, a question that has occupied the attention of both the chemist and the physicist, regardless of whether the homogeneous bodies are elements or compounds. In this discussion we will confine ourselves to a brief review of the present day views concerning the structure of the atom. From the facts of the natural degradation of radioactive elements and the bombardment of atoms of various elements, we find that all elementary matter is associated with the following particles—some or all of which may be considered as the building stones of the atoms: (a) the *electron*, 1/1845 of the mass of the hydrogen atom and associated with a negative charge of electricity; (b) the *proton*, or the hydrogen ion, being a mass with a positive electrical charge; (c) the *neutron*, having a mass approximately that of the hydrogen atom but electrically neutral; (d) the *positron*, having the same mass as the electron but associated with a positive electrical charge; (e) the *mesotron*, a recently discovered particle of fleeting existence; (f) the *neutrino*, as yet of doubtful existence. At the present time we can hypothetically build atoms from the electron, the proton, and the neutron which will meet many of the specifications imposed by physics and chemistry of which the following are a few: these structures must account for the facts of periodicity in the properties of the elements; the facts of ionization; the valence theory; the existence of isotopic elements; the facts of radioactivity; and facts of spectroscopy.

As an illustration, may we discuss the existence of isotopic elements as related to their possible hypothetical structures. Our present point of view regards the atoms of ordinary or light hydrogen as consisting of a nuclear proton which bears one positive electrical charge, and one planetary electron with its one negative charge revolving about the positive nucleus at different energy levels. Physical theory tells us that if energy is absorbed by the atom, the electron moves to a higher energy level but if it falls to a lower energy level it emits energy. The energy so absorbed or emitted gives rise to absorption or emission spectra respectively. The quantity of energy so absorbed or emitted can be easily calculated from a knowledge of the light frequency and Planck's Constant or the quantum. For these ideas we are indebted chiefly to Rutherford, Bohr, and Sommerfeld.

Deuterium, or heavy hydrogen, is also regarded as having a nucleus consisting of one proton, and, in addition thereto one neutron, a particle that is electrically neutral; in other words, the nucleus of the heavy hydrogen atom is approximately (2.0186) double the weight of the ordinary, or the light hydrogen atom. Revolving about this nucleus also is one electron as in the case of the light hydrogen atom. Hence, we see that the electrical charge on the nuclei of both light and heavy hydrogen atoms is the same, i. e., one positive charge; and each of these atoms has but one electron, i. e., one negative charge. From these two illustrations it is evident that within the nucleus resides practically all the mass of the atom since the mass of the electron in each case is negligible.

The fact that these two different atoms have the same nuclear charge but different nuclear mass is one of the first importance. In his now classical experiments, Moseley, in a study of the X-ray phenomena produced by the use of several different solid elements as targets in his apparatus found that the frequency of the emitted X-ray in each case was a function of the ordinal number of the element used. These ordinal numbers, i. e., hydrogen, 1, helium, 2, lithium, 3, and uranium, 92, are identical with the charge on the nucleus. They are called "atomic numbers." Out of this situation emerges the interesting fact that the isotopic species of a given element have the same atomic number regardless of the atomic weights of the several species. The composition of the three isotopes of magnesium to which reference has been made above is given in the following table:

	Particles Composing the Nucleus		Extra-Nuclear Particles	Number of Electrons in Energy Levels		
Symbol	Protons	Neutrons	Electrons	K-shell	L-shell	M-shell
$_{12}Mg^{24}$	12	12	12	2	8	2
$_{12}Mg^{25}$	12	13	12	2	8	2
$_{12}Mg^{26}$	12	14	12	2	8	2

The electrons are distributed about the nucleus at different energy levels or shells as shown in the above table. Since their number and distribution is the same in each case, it is clear why the chemical reactions of the isotopic species of a given element are generally identical.

We must now be reminded that recent discoveries have shown that the proton, neutron and the electron are not sufficient to account for the facts of radio-activity. This may be illustrated by the behavior of radio phosphorus whose formation and behavior are shown by the following reactions:

(a) $_{13}\text{Aluminum}^{27} + {}_{2}\text{Helium}^{4}\text{(ion)} \longrightarrow {}_{15}\text{Phosphorus}^{30}\text{(radio)} + {}_{0}\text{Neutron}^{1}$

(b) $_{15}\text{Phosphorus}^{30}\text{(radio)} \longrightarrow {}_{14}\text{Silicon}^{30} + {}_{1}\text{Positron}$

It is now believed that the positron is a manifestation of the binding or cementing energy which holds the nuclear portion of the radiophosphorus atom together until the explosion occurs. Whether the mesotron, or meson, also functions as a cementing force cannot be definitely stated at this moment.

Thus far in our discussion of atomic structure we have confined ourselves to the use of building stones which were particles of definite magnitude. In 1924, de Broglie, the Frenchman, suggested that discrete particles, such as atoms, ions, and electrons should have wave properties as well as those of a corpuscular character, a point of view which reminds us of the discussion concerning the wave and corpuscular theories of light. This postulate was experimentally verified by Davisson and

Germer in the Research Laboratories of the Bell Telephone Company in 1927 when they found that a stream of electrons showed diffraction and interference phenomena when reflected from the surface of a crystal. In the following year (1928), G. B. Thomson obtained the same results when he projected a beam of electrons through a very thin gold film. Two years later (1930) Stern and Eastermann demonstrated that atoms of hydrogen and helium also have such wave properties in addition to those due to their corpuscular character. Out of the implications of these discoveries and the quantum mechanics emerged the powerful wave mechanics by means of which it was possible to determine the exact number of energy levels in the hydrogen atom and thus verify the assumptions which Bohr had made with reference to the spectrum of this element.

Since the atom has both corpuscular and wave properties it is evident that a mechanical structure alone is not sufficient to serve as a model of the atom—a particle which is so very complex in its properties.

In the beginning of our discussion it was stated that Dalton had formulated his theory in order to give significance to the laws of chemical combination and the law of indestructibility of matter. Since his theory advocated that matter was atomic in nature, the most natural conclusion for him to make was that the individual atoms themselves must also be indestructible. Hence, he asserts in postulate three that "No new creation or destruction of matter is within the reach of chemical agency." The spirit of this postulate has been one of the classical principles in the physical sciences. The following would be another expression of Dalton's thought. "Within the limits of experimental accuracy no change in the total mass can be detected as a result of any transformation which matter may undergo."

In 1906, Landolt performed a series of chemical experiments in sealed glass containers to test the validity of the law of conservation of mass and as a result he found that his experimental differences were of the order of only one part in ten million, i. e., a few hundredths of a milligram in 100 grams of reacting materials, a value so small that its significance could well have been disregarded.

Thanks to modern theoretical physics, the principle of the conversation of mass is merely one aspect of the principle of the conservation of energy, or, as Berthoud has so well expressed it, "matter and energy are not principles of different natures; they comprise a physical unity." This would imply that matter and energy are reversibly interconvertible. Einstein has expressed the relationship by his well known equation

$$E = mC^2$$

in which E is energy, m is the mass, and C is the velocity of light. This equation means that "an increase in the energy of a body means an increase in its mass, and that every form of energy has an equivalent mass." Kaufmann, a German worker, seems to have furnished experimental evidence for these relationships when he found that an increase in the velocity of an electron produced an increase in its mass.

By the use of Einstein's equation, it can be shown that the energy evolved in the formation of one gram molecular weight of water from its elements has a mass of 3 millionths of a milligram. When compared to the 18 grams of reacting materials this seems to be a very small quantity, but it is none the less a very real one (3×10^{12} ergs).

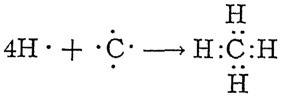
Thus it becomes clear that there must be an increase in mass in all endothermic chemical changes in quite the same manner as there must be a diminution of mass in all exothermic chemical changes.

The contribution of present day workers in the physical sciences has greatly enlarged the meaning of the relationship which Dalton enunciated in this postulate. Today as well as in Dalton's time the fundamental character of this great generalization remains unchanged, i. e., we are only becoming aware of its comprehensive character.

Our natural philosopher was also concerned with the mechanism of chemical reactions as is evidenced by postulate five wherein it is stated that "if two bodies are disposed to combine, then their combination takes place by atoms." The chemist has always been interested in knowing the number of atoms of one element which will unite with a definite number of atoms of another element, an inquiry out of which the theory of valence was born. Today we believe that the electronic section of the atom, i. e., the extra nuclear part, is the one that functions in chemical reactions, that is, that the forces to which John Dalton referred are electrical in their nature. This is equivalent to saying that today we regard the valence concept to be an electronic one. If this is true and our present picture of the orientation of the electrons about the nucleus is correct, we have reason to expect a number of different electronic mechanisms whereby chemical union would take place to form at least three types of compounds whose existence are realized in the following classes:

1. *Electrovalent Compounds:* These compounds are formed by the transfer of electrons from the metallic to the non-metallic element, an action which yields a positive ion and a negative one. These changes may be represented by the union of a sodium atom to a chlorine atom to form sodium chloride, a reaction in which the chlorine atom acquires an electron from the sodium atom thus leaving the sodium with a positive electrical charge and the chlorine with a negative charge. These charged particles are called ions. An X-ray examination of solid sodium chloride confirms the view that the crystal of this compound contains the ions of its components and not its atoms.

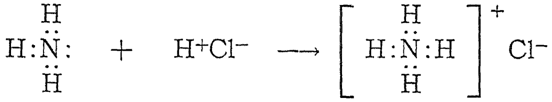
2. *Covalent Compounds:* The covalent compounds are formed by a mutual sharing of electrons of the elements composing the new substance, a point of view which should be credited to G. N. Lewis, of the University of California. In general, the chemical bond thus formed consists of two electrons, one each having been contributed by two individual atoms. The bond thus formed is usually equivalent to the single bond of an organic compound. This electronic concept of shared electrons may be represented by the marsh gas molecule as follows:



$$4\mathrm{H}\cdot + \cdot\underset{\cdot}{\dot{\mathrm{C}}}\cdot \longrightarrow \mathrm{H}:\overset{\mathrm{H}}{\underset{\mathrm{H}}{\underset{\cdot\cdot}{\ddot{\mathrm{C}}}}}:\mathrm{H}$$

It should be pointed out that the theoretical physicists, Heitler and London, in their studies of the nature of valence assumed that the electron pairs which give rise to a covalent bond must be of opposite spin.

3. *Coordination Compounds.* In coordination compounds the "two electron valence bond" is furnished by a single atom which in turn may unite with another atom in order to bring the outer shell of the second atom up to eight or more electrons. The following is a familiar illustration:



$$\begin{array}{c}\mathrm{H}\\ \mathrm{H:\overset{..}{\underset{..}{N}}:}\\ \mathrm{H}\end{array} + \mathrm{H^+Cl^-} \longrightarrow \left[\begin{array}{c}\mathrm{H}\\ \mathrm{H:\overset{..}{\underset{..}{N}}:H}\\ \mathrm{H}\end{array}\right]^+ \mathrm{Cl^-}$$

$$\text{Ammonia} + \begin{array}{c}\text{Hydrochloric}\\ \text{Acid}\end{array} \longrightarrow \text{Amonium Chloride}$$

The bond here consists in the nitrogen having a "lone pair" of electrons, or a duplet available for the hydrogen ion. Thus we see that the modern conception of the structure of the atom furnishes us a satisfying mechanism whereby chemical combination takes place between atoms as was postulated by Dalton. Furthermore, we have been able to classify many compounds into groups by reason of the electronic mechanism whereby chemical union takes place.

Postulate VI. The sixth and last postulate assumes that "in an elastic gas each particle occupies the center of a comparatively large sphere and supports its dignity by keeping all the rest, which by their gravity or otherwise are disposed to encroach upon it, at a respectful distance." This quaint statement is easily recognized as the now universally accepted kinetic-molecular theory of matter. It is said that the kinetic concept involved in this postulate comes to us from Daniel Bernouilli, a Swiss mathematical physicist, who, in 1738, developed a kinetic theory of gases.

That Dalton was correct with reference to his statement concerning each molecule occupying "the center of a comparatively large sphere" is evident from the fact that the space between the molecules composing steam at 100° is 99.94% of the total volume, i. e., the actual molecules of steam occupy only .06% of the total volume, i. e., only 6 cc. in 10,000 cc.

This postulate also tells us of the unceasing motion of gaseous particles. One of the most convincing pieces of evidence of molecular motion is the Brownian movement. As a result of Perrin's work referred to above on the Brownian movement in emulsions, Ostwald, *one* of the early German workers in physical chemistry, was moved to say that "the agreements of the Brownian movement with the requirements of the kinetic hypothesis justify the most cautious scientist in now speaking of the experimental proof of the atomic theory of matter." In this connection it only is necessary to refer to the great contribution made to the science of chemistry and physics by the kinetic molecular approach to a vast number of well known chemical and physical phenomena.

Finally, in the light of present day knowledge, we arrive at the following conclusions in evaluating the postulates of John Dalton enunciated one hundred and thirty-five years ago.

1. Modern physics and chemistry furnish convincing laboratory evidence for the existence of atoms as John Dalton set forth in his theory.
2. The degradation of these atoms into other particles is a natural as well as a laboratory process.
3. The atoms of a given element are not homogeneous as Dalton

believed, but they are found to possess different masses. These different species are known as isotopes.

4. Atoms consist of the following corpuscular particles, the electron, the proton, the neutron, the positron, the mesotron (meson), and possibly the neutrino.

5. Atoms have wave properties as well as those properties arising from their corpuscular character.

6. The atoms consist of a nucleus made up of protons and neutrons while the extra-nuclear portion of the atoms consists of electrons. The isotopes of a given element are due to the variable number of neutrons.

7. The spirit of Dalton's view that no new creation of matter is within the reach of chemical agency has been greatly enlarged in its meaning.

8. Dalton's view that chemical combination takes place by atoms has been greatly enriched by our present electronic conception of valence.

9. Dalton's Kinetic picture of the atoms has in no wise been changed.

The purpose of this discussion has been to trace in brief outline the life history of one of the basic theories underlying so much that is fundamental in the fields of knowledge represented in this Academy. It would seem that the enlargement of the points of view in certain of these postulates and other changes which have been made by reason of later experimental and theoretical considerations would be fairly typical of the philosophical process which aids us in a better understanding of the surroundings in which we find ourselves as human beings. In closing may I quote from the dedication inscribed by Charles Daubeny in his book entitled "Atomic Theory"—published in its second edition in 1850—a dedication by an academician who had an appreciation of the scholarship of John Dalton.

TO

THE MEMORY OF
JOHN DALTON, F. R. S.

Late President of the Literary and Philosophical Society of Manchester,
Corresponding Member of the Academy of Sciences of the Royal Institute of France, and Honorary, D. C. L. of the University of Oxford,

THE FRAMER OF A THEORY
WITH RESPECT TO THE MODE OF COMBINATION BETWEEN BODIES,
WHICH STANDS FOREMOST AMONG THE DISCOVERIES OF THE PRESENT AGE,
FOR THE UNIVERSALITY OF ITS APPLICATIONS,
AND THE IMPORTANCE OF ITS PRACTICAL RESULTS;
HOLDING THE SAME KIND OF RELATION TO THE SCIENCE OF CHEMISTRY,
WHICH THE NEWTONIAN SYSTEM DOES TO THAT OF MECHANICS:
AND THROWING LIGHT,
NOT ONLY UPON ALL THE ORDINARY SUBJECTS OF CHEMICAL INVESTIGATION,
BUT EVEN UPON THOSE MORE SPECULATIVE QUESTIONS
WITH RESPECT TO THE CONSTITUTION OF MATTER,
WHICH SEEMED TO LIE BEYOND THE REACH OF
EXPERIMENTAL INQUIRY.

RESEARCH ON THE CENTRAL AUDITORY MECHANISMS: SOME RECENT METHODS AND RESULTS[1]

E. A. CULLER,
University of Rochester

Whenever I speak upon the topic of hearing, I am reminded of an incident which occurred some years ago at a meeting of the National Academy of Science. A young man from one of our large universities had just reported a study in audition. As he concluded, Dr. Cattell arose—dean of American psychology and Nestor of American science. His first comment was to this effect: "Whenever you think you've discovered something new about hearing, turn to Helmholtz and you'll find it there." This tribute to the greatest experimental theorist in the history of acoustic research was indeed well deserved; but it was considerably more true when spoken fifteen years ago, than it is today. We now know some things about hearing that even Helmholtz, with his unrivaled insight, did not perceive.

This new knowledge is due, in large part, to new methodology. I need not remind you that the milestones in scientific progress are marked by new methods of research. Emphasis upon methodology is a cardinal distinction between the man in the laboratory and the man on the street. Whenever I speak to laymen about our work, I am often reminded by my hearer that he is not interested in methodology; what he wants are facts. He makes the statement with something of an air, as though he prided himself on being hard-headed and practical. But we all know, if we know anything about science, that the observations we get are a function of the methods we employ; that facts are the fruit of operations. For that reason let us begin with a few methods that are basic in auditory research as a means to understanding some of the facts which I wish to report.

The first method historically was doubtless *clinical*. If everybody had perfect and uniform hearing from birth until death, never suffering any impairment because of accident or disease, it is doubtful that hearing would ever have been a problem. Because some of us hear better than others, because we hear better early in life than later, because hearing may be completely destroyed through some injury, we are forced to think about the mechanisms of hearing—how they operate and what can be done to restore them. In other words, the accidents of Nature prod man to research. In this sense, Nature may be called the first experimenter. One of the great contributions of Darwinian theory is its revelation that the world we inhabit is an experimental instead of a static universe. In the clinical method Nature sets the problem and man tries to solve it. A patient whose hearing disturbs him appears in the consulting room of an otologist; who thereupon, in addition to other tests, plots a complete audiogram of each ear. He thus determines as well as possible the locus and nature of the malady. Ofttimes little can be done beyond prescribing a hearing-aid. The patient is then examined year by year to note what changes occur and finally, if the physician lives long enough and the patient dies soon enough, the ears which have been so often tested are removed and sectioned in order to correlate their anatomical deficiency with the functional hearing-loss. The procedure is sound but has several great defects. 1. It is insufferably slow. The patient may live longer than the physician; so that the answer to a simple question of fact may require several generations of careful work by many investigators. 2. But a still graver difficulty is that Nature, although the first experimenter, is unquestionably one of the poorest. A young man of the laboratory, who could not plan his experiment better than Nature does, would find it hard to win even a bachelor's degree. A clinical lesion usually implicates so many separable factors in the ear that it is quite impossible to say which one is responsilbe for the hearing-loss. At Johns Hopkins Medical School is located one of the world's most extensive collections of sectioned human ears, together with audiograms showing the functional condition of each one. This vast body of material has accumulated over many decades and represents a huge expenditure of time, energy, and money; yet I venture to say that we can learn more by the use of modern experimental techniques in six months from a cageful of guinea pigs about localization of function in the cochlea than we can from this great assemblage of clinical evidence. While the clinical method will never be superseded, its deficiencies are such that little real progress could be made until adequate *experimental* methods were devised.

---

[1] Communication No. 37 from the Laboratory of Physiological Psychology (Animal Hearing), which was transferred from the University of Illinois to the University of Rochester in 1938. This laboratory is maintained with aid from the Research Council, American Otological Society.

Of these experimental methods, the first to consider is *conditioning.* This term is familiar to you. It was bestowed by the Russian physiologist Pavlov and is illustrated in one form by the familiar laboratory picture in which a dog stands with one foot resting upon a metal grid which can be charged with a small electric potential. If you sound a tone about two seconds before the paw is stimulated, the animal will soon begin replying to the tone by withdrawing his foot from the grid. We say that he has been "conditioned" and now reacts to the sound as he formerly did to the shock. After conditioning has been established, the tone is made weaker and weaker. The animal continues to react as before until at last he begins to falter, responding sometimes but not always. With continued reduction of intensity, a point is eventually reached where no response occurs at all: this implies that the tone is now completely inaudible. This simple procedure has proved extraordinarily fruitful in studying problems of hearing. The older experimenters, who tried to get away from the limitations of the clinic, were impaled upon one horn of a dilemma. If they worked with human patients, they could test the subjects's hearing but they could not operate surgically on him. After all, we can't drill a hole in our neighbor's ear to see how that would affect his hearing. If, however, they tried to use animals, they could indeed operate on the subject but they were unable to measure what it *could* and *could not* hear. Until very recent times, effective laboratory research on hearing was blocked by this dilemma. Now, however, by the conditioning procedure we can train a dog or cat or guinea pig to react visibly to every sound it can hear, however faint, and thereupon measure its audiogram. We can then anesthetize the animal and make some well defined lesion in the acoustic tracts. As soon as the animal recovers from anesthesia, it will tell us by its reactions the exact effect of our lesion. By making comparative tests on our trained animals and on ourselves, we have proved that a test-animal is fully as reliable a witness as a good human patient. Almost every problem that arises in the otological clinic with human beings can now be tested with experimental controls in the animal laboratory.

Another experimental method which has proved of the greatest value in recent years is *electrical*. It has long been known that the activity of living cells is often attended by electric phenomena. So well was this understood even fifty years ago that these electric potentials were designated "signs of life." One could, for example, distinguish a living seed from a dead one by means of the minute electric currents generated by the former. There are, of course, other signs of life. A living cell will give off CO_2 at all times; an active cell will emit more CO_2 than a cell which is resting. This has been well demonstrated by an instrument known as the biometer or "life meter," which reveals that an active nerve fiber gives off fully twice as much carbon dioxide as the same fiber when at rest. Likewise living cells when active emit heat; even the minute nerve-cells generate small quantities of heat when they are conducting impulses. The peculiar advantage of electrical procedure is, however, that living cells can be studied *in situ* more readily than by any other means. Electric techniques are so highly developed that we can put an electrode against the inner ear or the auditory nerve, pick up the minute potentials therein generated, lead them through an amplifier into an oscillograph, and study their properties. The contribution of this method to understanding the function of the ear and its associated tracts is hard to overstate. What we may call the modern period of auditory investigation begins with the application of electric methods to the study of the cochlea and the cochlear nerve.

In many cases the two experimental methods, electric and conditioning, are applicable to the same problem. When used in combination, they constitute an extremely powerful tool for the study of acoustic mechanisms.

In recent years research by use of these methods has been principally of two kinds. 1. Some investigators have continued to study the activity of the cochlea in different animal-forms and to seek an adequate description of the peripheral structures and operations by which a sound-wave is converted into discrete nerve-impulses. 2. Others have examined the structural characteristics and functional problems of the neural conduction-system in its course from cochlea to cortex; the purpose of these studies being to describe and evaluate the neural events which unite the functional levels of the acoustic system.

It may be well to remind you that both the cochlea of the inner ear and the neural components of the acoustic system emit electric potentials when sound vibrations are impressed upon the ear. These two types of potential, however, differ in certain important respects. 1. Synchronized cochlear potentials can be detected as high as 6000 cycles or more whereas synchronized neural potentials seldom are reported beyond 2500 or 3000 cycles. 2. The cochlear potential usually resembles (apart from aural distortion) the wave form of the impressed sound, whereas the neural potentials look like similar potentials in other sensory nerves, being essentially monophasic and negative. 3. The cochlear voltages are many times as large as the neural, with the result that they spread by ordinary electric transmission to points several centimeters away from their origin. The neural potentials being much feebler can usually be detected only in close proximity to the nerve-cell which generates them. 4. Cochlear electrophonics, which thus spread in all directions by ordinary transmission, travel at considerably higher velocity than do neural impulses which propagate at the usual speed of nerve-impulses (e. g., 30 meters per second). 5. Cochlear potentials effectively resist narcosis whereas neural potentials are appreciably reduced by most anesthetics. 6. Cochlear potentials may persist for minutes or even hours after demise of the animal, though with reduced intensity, whereas the neural potentials commonly disappear at or just prior to death.

In accord with the original plan of this symposium, I shall confine myself principally to reporting some studies bearing upon the phenomena that occur in the neural acoustic system central to the cochlea; that is, studies which belong to the second group of investigations just mentioned.

1. I shall first notice a study now in progress by W. D. Neff of our laboratory on the effects upon hearing in the cat of partial section of the eighth nerve. Changes in sensitivity occasioned by local damage to the eighth nerve, which connects the cochlea to the brain stem, are observed by the conditioned-response technique. The cat is first conditioned until it responds clearly to any audible sound. The audiogram of the animal is then measured at the various octave frequencies from 125 cycles to 8000 cycles and, in some cases, for two additional octaves (62 cycles and 15000 cycles). When the animal's normal hearing is thus determined, the cochlea of one ear is destroyed so that all auditory impulses must pass to the brain via the nerve that is later to be partially sectioned. Destruction of the single cochlea results in surprisingly small loss of total sensitivity, usually about two or three decibels. (A decibel is the standard unit in acoustic measurements and is, very roughly, that difference in physical intensity of two tones which can just be perceived by a normal ear). As soon as the animal's thresholds for the several frequencies have been determined for the one remaining ear, the second and critical operation ensues. Under complete narcosis the eighth nerve of the intact ear is carefully exposed. The nerve tissue being quite soft can be removed in any desired amount by a suction-pipette so that part of the nerve is left intact but the remaining fibers are effectively interrupted. After the animal is sufficiently recovered

for testing, the postoperative limens are secured. Comparison of these limens with those which preceded the operation will, obviously, reveal the losses due to partial section of the nerve. Results to date reveal that a very small lesion brings no significant loss at any frequency, whereas with larger lesions, marked losses appear at several of the higher frequencies. Since the experiment is not yet complete and histological evidence is not yet available, interpretation must be tentative; but several conclusions are already obvious. First, not all fibers of the eighth nerve need be severed to render an animal deaf to certain frequencies. Secondly, the remaining intact fibers give at other frequencies the same sensitivity (limen) as did the whole nerve.

2. A second study was performed by Ades and his collaborators at the level of the medial geniculate bodies in the cat. These two nuclei, right and left, being the final way-station from cochlea to cortex, provide an ideal site for determining in what manner cochlear impulses are transmitted to the brain. The general procedure was as follows: The intact cat is first conditioned and its normal audiogram obtained for an adequate sample of the audible range (octave frequencies from 125 to 8000 cycles). Localized electrolytic lesions are then effected at corresponding points of the two medial geniculates. The cat is then retested to determine what losses, if any, have occurred in its hearing. Finally, the animal is dispatched and the brain prepared and examined by histologic methods.

Inspection of the audiograms shows that localized lesions in symmetrical areas of the two geniculates result in some attenuation of auditory sensitivity for all frequencies tested, but that the degree of impairment differs widely. The variation is not haphazard but in every case conforms to a definite pattern, the loss being greatest at one or two frequencies, graduating down to a minimum at those most distant from the focal frequencies. Cats with lesions in corresponding areas display a similar distribution of hearing losses. Loci for the several frequencies seem to be as follows: 8000 cycles, dorsal region; 4000, anterior; 2000, lateral; 1000, posterior; 500, medial. The lower frequencies, 250 and 125 cycles, were in no case attenuated to maximal degree, but apparently traverse the ventral side. The several loci thus appear to follow a linear course, beginning with higher frequencies in the dorsal section and circling downward to the ventral region where the lower frequencies appear.

3. The medial geniculate nucleus in the cat has also been explored by Coakley, using an entirely different method. If there is a spatial distribution of fibers within the nucleus, it should be possible to determine their position by recording the electric potentials generated in any given case by the active units. Accordingly, the distribution of potentials in the nucleus has been studied for five frequencies of stimulation arranged in octave steps from 125 to 2000 cycles. Since the potentials above 3000 cycles became so feeble as to be practically imperceptible, our data are limited to frequencies below that point. The potentials generated by an impressed tone were measured at about 120 points arranged uniformly throughout the nucleus and just beyond its margins. Of course only a small number of points could be studied in any one

animal but each point was examined in about six cats. Summarizing the results for all animals, we find that for each frequency applied to the ear, the potentials are maximal for amplitude in one region and become smaller as the needle is moved in *any* direction from this area. If these maxima are arranged in order of frequency, they constitute a figure similar to a conical helix. Further analysis of the data reveals the approximate course followed by each group of fibers. In addition exact synchronization between impressed frequency and neural pulses in the nucleus was observed up to 2500 cycles. This implies that, whatever number of negative (or positive) pulses is generated in the cochlea, the same number will still be found (up to 2500 cycles) in the neural action-currents of the medial geniculate.

4. E. A. Lipman has accumulated some material on cortical function in hearing. The procedure is similar to some already mentioned. The normal audiogram of a trained dog is first measured at the usual representative frequencies (125 to 8000 cycles). The entire temporal (acoustic) area of one side of the cortex is then removed and the animal's audiogram again tested. Even though only one side of the brain is now intact, hearing-losses are quite negligible, being in no case more than three or four decibels. The second and critical operation then follows in which a small localized part of the remaining intact side is removed with the suction-pipette. Postoperative tests again reveal what losses, if any, occur at each frequency.

In general the losses at a specific frequency are not large, about 10 decibels, but the results to date indicate that hearing losses are confined to the area comprised by the medial and posterior ectosylvian gyrus and the adjacent medial and posterior sylvian gyrus. Removal of cortex beyond this area seems to have no effect upon hearing. Thus far lesions in the ectosylvian gyrus are followed by losses at 500 cycles and below, whereas lesions in the adjacent sylvian area seem to bring losses at higher frequencies from 1000 cycles up. These results indicate that focalization of responses is not so sharp as elsewhere but still present. The exact locus for each of the several frequencies awaits further tests.

From these and other observations we may infer that different tonal frequencies, when impressed on the ear, actuate different areas or patterns of receptive cells within the cochlea and that the impulses thus generated traverse differential pathways to the auditory projection center of the cortex; but that the number of pulses per second passing to the cortex rises in step with the impressed tone, and thus provides a second clue by which the organism can perceive pitch. The *relative* contribution of these two factors (spatial and temporal) must await further analysis.

SOME SOCIAL ASPECTS OF DEAFNESS

E. R. ABERNATHY,
Superintendent, Ohio State School for the Deaf

Helen Keller once said: "I am just as deaf as I am blind. The problems of deafness are deeper and more complex, if not more important, than those of blindness. Deafness is a much worse misfortune. For it means the loss of the most vital stimulus—the sound of the voice that brings language, sets thoughts astir, and keeps us in the intellectual company of man."(1)

There is considerable truth in these few lines. Deafness strikes deep in the social roots of the individual who is so handicapped.

It is the purpose of this paper to present to you briefly some of the social aspects of deafness; this is with particular reference to the deaf as distinguished from the hard-of-hearing. To differentiate between these, the hard-of-hearing are those in whom the sense of hearing, although defective, is functional with or without a hearing aid; the deaf are those in whom the sense of hearing is nonfunctional for the ordinary purposes of life. The term "deaf and dumb" is no longer used as too frequently it implies stupidity which is not true of the group. Neither is the term deaf-mute an acceptable designation. The child who has been deaf from an early age does not speak because his deafness prevents the acquisition of speech in the normal imitative manner. Organically his organs of speech are normal. Deaf babies cry, coo, and babble, much as other babies do. While the average deaf child can be taught speech, he does not acquire it unless he is given special instruction.

Deafness not only acts as a barrier to speech but blights the child's language. The little hearing child hears words repeated scores of times and early begins to link these words to objects or actions. In place of language a system of crude gestures is built up for the deaf child. These are necessary for the child to make his wants known. The means of communication is so limited that it seriously retards his progress. Explanations are difficult to make and are seldom or inadequately made. Parents finding that they cannot reason with the child or make explanations, give him what he wants. Of course if he doesn't get it, he frequently resorts to tantrums. The gestures used generally relate to the child and not to others. This tends to make his world a self-centered one, with little consideration for others.

While some parents indulge their deaf children as far as they possibly can, others err in the other extreme by punishing them for misbehavior that resulted from a lack of understanding on the part of the child.

It is apparent that little deaf children must experience a feeling of frustration in not being able to express themselves or inquire into the how, what, who and why of the world about them.

Such characteristics have been commented on by others. I refer you to Brunschwig, "A Study of Some Personality Aspects of Deaf Children,"(2) and also Ewing and Ewing "The Handicap of Deafness."(3)

It is perhaps worthy of mention here of the weary and often painful rounds on which these children are taken in the hope that their hearing will be restored. Frequently after the family physician has attended them for some time they are referred to an otologist. Though the otologist may tell the parents that the child is irrevocably deaf they continue to go from doctor to doctor, to charlatan and quack, administering pills, salves and worthless nostrums. Two or three years ago we had a boy return to school with a box full of pills to restore his hearing. There were seven different kinds of pills in the box, and he was to take one of each after each meal. While faith cures are not to be regarded as painful experiences, it is not uncommon to have children kept out of school for long periods of time awaiting such cures to take effect.

Unfortunately most parents do not require what they reasonably could of their small deaf children. Swayed by sentiment, they think of them as poor little deaf children who are unable to do anything for themselves. A year ago we had a six-year-old boy enter school whose grandmother still gave him his milk in a nursing bottle. While this is unusual it shows the extent to which "babying" can be carried. Each year we find that a large proportion of our beginning children can neither feed nor dress themselves properly, yet they could easily have been taught these things had their parents approached these problems sensibly. Through a lack of understanding, and proper handling, behavior problems appear and grow unchecked. The mother of one of our small boys, who caused his parents no end of annoyance and despair, told me that she had taken the child to a well known surgeon, and asked him to open up the boy's head to see what made him so mean. At school—after he has settled down from a home visit—he is a nice little fellow.

Paralleling a statement by Druschba (4), it is as true of deaf children as it is of hearing, that they are neither good nor bad originally. The character and behavior problems that arise, come not from their deafness, but from faulty or ineffectual methods of training. It is pertinent to observe at this point that little deaf children whose parents are deaf are quite generally more normal, both in behavior and achievement, than deaf children from hearing families.

When the deaf child reaches school age he comes to another social turning point. Occasionally such children are not sent to school at all; more frequently the parents delay sending them for two, three, or more years. In 1937 we admitted a girl who was then twenty years of age. The girl appeared to be of good mentality but her mother had simply kept her at home. It was on the insistence of a sister that she was finally brought to school. She could not answer such simple written questions as "How old are you?" and "Where do you live?" This girl is now doing work on the level of pupils who have been in school six years and the outlook in her case is good. Sometime ago I received a letter from a woman concerning her deaf sister who was then forty years old. The mother had taken care of her during her lifetime. After the death of the mother, the deaf woman lived with her sister. The letter stated that while she was quite intelligent, she was unable to read or write. It was evident that she was proving to be an unhappy burden on the family. Of course this woman was beyond the reach of our school. While these are exceptional cases, they show how dependent the deaf are on proper instruction.

Today practically all educable deaf children are sent to some school. It is true that some of them are to be found in the class rooms of regular public schools. This comes about because the parents are either unaware of facilities for special instruction or because they are unwilling to let them go away to school. Through a lack of discernment or indifference on the part of public school authorities they are allowed to remain. Sometimes intelligent deaf children are kept in these classes and both regarded and treated as feeble-minded. Socially their deafness isolates them from other children. Usually their hearing schoolmates ignore them, occasionally they are teased or made the butt of practical jokes. If they remain in a school for the hearing for any length of time, it is a common practice to push them on every year or two without regard to educational achievement. In the last few years several children have come to our State School after having an experience of the type described. One girl, whose father was a member of the local board of education, had been promoted year after year until she reached the eighth grade where she was failed by a teacher who had just come into that school system. The father had had some misgivings over the school promotions of his daughter. These misgivings were not without foundation; we found that the girl's educational level was around the second grade. Socially and educationally maladjusted, children of this type enter our schools for the deaf, literally broken in spirit and with a defeated outlook on life. While there is a sufficient number of these children to justify mention, the percentage of them is small. Most deaf children enter schools for the deaf without long delays.

For the little child who is profoundly deaf there are two principal means of instruction; he may be instructed either orally, or he may be instructed manually. Each of these approaches has its shortcomings as well as its advantages. The social aspects of both are such that they should be discussed here.

The oral approach consists of teaching the child speech and speech-reading (or lip-reading as it is frequently called) and also using this means of communication in regular class-room activities. To appreciate what this involves it is necessary to know something of the procedure.

Speech instruction begins with the teaching of the elementary English sounds, the consonants and the vowels. Some of these are easily taught, others are much more difficult. One of the first consonants taught is H, which is simply an expulsion of the breath through the open glottis. The child readily learns this sound by imitation. Usually the first vowel taught is Italian A or AH. In producing this sound no modification by the lips is necessary; the tongue remains flat in the mouth. Contrary to popular belief, it is not difficult to get voice from a deaf child. Usually they understand by watching the teacher and feeling the vibration in her throat. However the quality of the voice is another matter. The child, not hearing the sound he is producing, may give it in an unnatural and displeasing voice. Considerable effort is made to obtain a good quality of voice in teaching the first vowel. The development of other vowels and consonants is more difficult, the formation of some of them being quite complex. These are taught in a variety of ways, such as comparing or contrasting them with sounds already learned; by manipulating the child's tongue; or drawing diagrams showing the required position of the tongue and other vocal organs. The child is taught to put these sounds together to form words, to syllabify words and accent them, and to phrase sentences.

The companion of speech is speech-reading. This is developed from a simple beginning. The child is shown some small toys such as a ball, a fish, and a car. The names of these present a dissimilar appearance on the lips and the average child is soon able to select the proper toy by watching the teacher's lips. Speech-reading is gradually extended to include familiar objects and actions. The level of attainment sought by the end of the first year, in the majority of cases, is some 150 nouns and 25 to 35 verbs. These he can recognize by speech-reading, can speak them orally and can write them.

For children who make poor and what is judged inadequate progress orally, some schools provide manual instruction. The manual means of conversation includes the use of the one hand manual alphabet by which words are spelled out letter by letter, A, B, C, D, etc.; it also includes the use of conventionalized signs. Common words may be either spelled or signed, for example, light is spelled (demonstrated) or it is signed (demonstrated), the placement and motion of the fingers, indicating the rays of light. For classroom purposes finger spelling is given decided preference over the use of the sign language.

While the above is a very brief presentation of the oral and manual means of instruction it is probably sufficient to serve as basis for discussing some of their social aspects.

Oralism seeks to make the deaf child a participating member of the hearing world. In this connection one frequently hears the phrase "Make the child normal." The fact that the practical accomplishments of oralism fall considerably short of this ideal does not materially lessen the appeal of such phrases to the majority of parents and the general public. This appeal combined with the desire of parents to have their children live at home and attend a special school, accounts for the large number of day schools for deaf children, all of which are purely oral schools. Oralism occupies a definite and useful place in the socializing of deaf children. The child who becomes adept in speech-reading and achieves clear speech enjoys an advantage over the child who is not so fortunate in these accomplishments. It is a fact, however, that most hearing people would find only a very small percentage of deaf children with understandable speech and good speech-reading. The large majority find conversation with anyone but close acquaintances difficult and will ordinarily resort to pad and pencil. In considering the social aspects of oralism this must be taken into account for it means that the general public will find that conversation with the ordinary deaf person must be carried on by means of pad and pencil. Furthermore, even the few who do have good speech are often reluctant to make use of it in talking to strangers. Some fear that they will mispronounce words. They know of course that hearing people frequently mispronounce words, but fear that their mispronunciations will not be of the ordinary variety. Thus a deaf man may make three syllables of the word Chinese and call it Chin -e-see; there is nothing in the word itself to guide him. Right here, let me say that it does not take much of a defect in speech to distract ordinary listeners; when this happens their attention focuses on the defect rather than on what is being said with the result that the sentence has to be repeated. If the deaf person is sensitive about his speech, he becomes more reluctant to use it in public after a few such experiences. An acquaintance of mine is a capable and intelligent deaf woman. She is an excellent speech reader. Her speech is easily understood and therefore when she was a student in Gallaudet College, the national college for the deaf in Washington, she was frequently called on to address hearing groups. On one such occasion when she was addressing a group of hearing teachers she happened to look down into the front row and see one woman say to another, "It's remarkable, but isn't her voice peculiar?" She said that it took her years to get over that remark.

Speech-reading is regarded by the ordinary individual as something akin to another sense. It is not surprising therefore that usually too much is expected. There are of course the few whose speech-reading ability is amazing and such cases have been dramatized and publicized. Because a man is a good speech-reader, people expect him to be able to sit in a dimly lit church, at a considerable distance from the minister and understand what is said. Several profoundly deaf people have attended Ohio State University. Usually they get very little from the lectures through speech-reading. The instructor paces back and forth, or draws a diagram on the board, explaining it as he draws. Scattered student discussions in large classes are equally impossible to follow. As might be expected under such difficult circumstances, the percentage of deaf people who are able to attend colleges for the hearing is small. Those who do generally have some one take notes for them. Through conferences, assigned readings and reports they are able to cover the courses. The majority of the deaf who attend college go to Gallaudet College, a federally supported institution in Washington, D. C.

Some speech formations are relatively easy to read; others are quite difficult. Because a speech-reader has understood a greeting such as "How are you?" most hearing people assume that he will understand whatever follows it, even if it happens to be a sentence like "It's a nice day, isn't it?" The latter expression will try the best of speech-readers as many of the speech formations involved are not discernible to the eye.

There are numerous other stumbling blocks for the speech reader. About half of the words used in ordinary conversation have other words of similar appearance but different meaning. As an example the following words present practically the same appearance: main, made, mate, bait, bayed, paid, pain, pained, paint, pate. He depends on the context to determine which word has been used. If you were to use the cliche "sweet sixteen," it would be read as such because of the context rather than "sweet sixty," which presents the same appearance.

Another pitfall for the speech-reader is the effect of modulation, which he misses entirely. By modulating the voice we can change the whole thought of a sentence.

It must be remembered that speech movements are fast, some of them are concealed and the differences between many of them are fine. Furthermore, no two people speak alike. Placed in a group of hearing people, the speech-reader finds himself at a decided loss, because of the rapid shifts in conversation and the fact that he must pay close attention to get what any one of them is saying.

In spite of these difficulties speech-reading is of inestimable value and the social advantages apparent. In our schools for the deaf these social and educational advantages are given full consideration. Speech and speech-reading can be of real value to an individual even though he may not be able to converse with every stranger through these media. If oral conversation is sufficiently intelligible for home and school use it is of practical value. Through it a child becomes a participating member in the life of a hearing family. The probability is greater, at least in most cases, that his parents will talk to him in complete and connected sentences. Otherwise the tendency is to write or laboriously spell out with the manual alphabet clipped phrases or single words. Generally speaking, hearing parents do not acquire a facile use of the manual alphabet or the sign language. This matter of unrestricted conversation in the home is an important factor in the child's acquisition of language, which is a major problem with deaf children.

Educationally there is a sharp difference of opinion as to the extent to which oral training should be pursued. Some schools hold that all deaf children should be orally taught and offer nothing but oral work in their schools. Generally these schools contend that a child will progress as satisfactorily by oral means as by any other; if they make poor progress in an oral class, their progress will in any case be poor and the end values of oral training will be of greater value.

Other schools hold that while oral instruction is both desirable and advisable in the majority of cases, that there is, never-the-less, a sizable number of children for whom it is not a practical approach to either their educational or social problems. The majority of the residential schools for the deaf in the United States are in this group. These schools offer both oral and manual types of instruction, that is they have classes that are orally instructed and classes that are manually instructed. They contend that when it is clearly demonstrated that a child's speech-reading ability is so inadequate that he can get only random words and his speech is unintelligible, even to those who know him well, then it is time to substitute some other means of communication. Of the two considerations, more weight is given to his speech-reading ability. In such cases these children are transferred to classes that are manually instructed. For instructional purposes the manual alphabet is given preference over the sign language because it involves extensively the use of language. While the sign language can be used to convey ideas it does little for the individual in terms of a reading or writing vocabulary. A person may know a number of signs without being able to manually spell or read the written equivalent of a single one of them. A few years ago an illiterate deaf woman called at our school. While she could neither read nor write she could carry on an intelligent conversation through the medium of the sign language. For the child who sits bewildered in an oral class, the manual class, through the use of the one-hand alphabet, provides an easily understood means of communication. These schools hold that they will educate children orally if possible; if it is found impractical to do so, further insistence will defeat both educational and social purposes.

The oralistic view-point is that through speech and speech-reading the social field of the deaf person is so widened as to bring him into normal or at least more acceptable relationship with the hearing world; the manualistic viewpoint grants that this is true in some cases but contends that since free social relationship with the hearing world is denied to the majority of deaf people, because of the inadequacy of their speech and speech-reading, they are automatically isolated from the hearing. Therefore, they believe that the social field, in such cases may best be enlarged through the medium of the manual alphabet and the sign language, for it brings normal relationships within the group, whereas none would be possible otherwise.

Manual conversation is a mixture of signs and finger-spelling. Signs are used for the common words; finger-spelling for proper names, technical or unusual words, and sometimes short words. The speed of manual conversation is only slightly less than that of normal speech. For a sizable group of the deaf it is a living and fluid means of communication; it gives spontaneity to their social events and is a necessary part of their lives. As it is clearly distinguishable at a distance, it is used for lectures, sermons, and plays. It is commonly used at social gatherings of the deaf. At any such gathering may be found a number who have had oral training but for social purposes, find fuller participation and greater social satisfaction in group activities through the medium of signs and finger-spelling.

With respect to both the oral and manual methods of communication it must be remembered that each has its function and each contributes to the happiness of a large group.

The acquisition of language is a major problem for the deaf. From childhood through adult life they struggle with the idioms and irregularities of the English language. A little girl who had gone home for the summer wrote of the good time she was having. In her letter she said: "I am hot water in the face," which was her way of saying that it was warm and her face was covered with perspiration. Not hearing words and phrases used countless times, it is not surprising that the deaf are at a disadvantage. The fine distinctions made in language are difficult for them, hence they may express themselves rather bluntly. The peculiarities in the written language of a deaf man attract more attention than the grammatical mistakes of a hearing man. Because of these peculiarities in English, hearing people sometimes underestimate the deaf individual. However, language difficulty is undoubtedly one of the most burdensome concomitants of deafness and its effect is more profound than is generally realized.

One of the commonest misconceptions about deaf children is that they are a morose and unhappy group. This concept is fundamentally untrue. The little deaf child is isolated and feels it when in the company of little hearing children. He is naturally bored and unsocial in such circumstances. Brought to school and associated with other deaf children he is soon a happy and participating member of the group. These children meet on an equal footing and in the give and take relationships, self-reliance is developed. School life with its more normal associations brings about a change from a self-centered little child to a more social individual. Under such conditions many of the pre-school behavior problems disappear. It is frequently observed by teachers who have taught both deaf and hearing children that as a group the deaf children are better behaved. Recently a hearing survey (5) was made in the Boys' Industrial School. In over 700 cases we found not one profoundly deaf boy and only the normal incidence of hearing defects. From this it appears that hearing disturbances do not precipitate gross behavior problems.

Schools for the deaf, like schools for the hearing, have children who in mentality range from superior to dull. While Pintner (6) places the I. Q. of the deaf as being close to 80, on the average, the fact remains that it is much more difficult to establish I. Q.'s in the case of the deaf than in the case of the hearing. From the standpoint of adjustment and ability, it is significant that the adult deaf population is largely self-supporting. With the exception of those who teach in schools for the deaf, very few enter any of the professions. Occupationally, large numbers of them are to be found in the skilled and semi-skilled trades with good industrial and employment records.

In this day of governmental benefits for various classes, it is noteworthy that the deaf neither seek nor want pensions for their group as such. In this state they maintain and manage their own home for the aged and infirm deaf. They resent any gesture of charity. Beggars professing deafness are almost always impostors. The deaf make good citizens and contribute to the general welfare. They neither feel, nor want others to regard them as an unfortunate group.

REFERENCES

(1) **Keller, H.** Helen Keller in Scotland. London, Methuen and Co., 1933, p. 68.
(2) **Braunschwig, L.** A Study of Some Personality Aspects of Deaf Children. Contributions to Education No. 687. New York, Teachers' College, Columbia University, 1936.
(3) **Ewing, I. R.**, and **Ewing, A. W. G.** The Handicap of Deafness. New York, Longmans, Green and Co., 1938.
(4) **Druschba, A.** Die Erziehung der Taubstummen. Vienna, Kaiser 1.—Konigl. Schulbucher Verlag, 1913, p. 47. (Translation cited in (2), supra, p. 12.)
(5) Survey of the Boys' Industrial School. At present in manuscript form; to be published under the direction of T. C. Holy, Arps Hall, Ohio State University, Columbus.
(6) **Pintner, R.** Intelligence Testing. New York, Henry Holt and Co., 1931.

THE DEVELOPMENT OF HIGH VOLTAGE FOR THE PRODUCTION OF NEUTRONS AND ARTIFICIAL RADIOACTIVITY

E. U. CONDON, Ph.D.,
Associate Director, Westinghouse Research Laboratories,
East Pittsburgh, Pa.

Eight years ago neutrons and the phenomenon of artificial radioactivity were discovered, following closely on the first work on artificial transmutation of the elements. In the years that have followed there has been a tremendous advance in our knowledge of fundamental physics of the atom as a result of these discoveries, a big development of equipment for producing and measuring the new radiations, and a wide recognition of their great potentialities for medicine. I understand it to be the function of our symposium this morning to make a rapid survey of this field from the particular standpoint of the cancer problem. In opening the discussion, I shall undertake only to present the physical side of the subject, properly leaving to my associates a discussion of the biological and medical phases.

Let us start by recalling that we now know that the atoms of matter are made of a central nucleus, composed of protons and neutrons and hence charged electrically positive, surrounded by enough electrons to make the atom as a whole electrically neutral. All the development of atomic physics from 1912 to 1930 was concerned with the study of the outer electronic structure—the decade from 1930 to 1940 has seen the interest shift almost entirely to the internal structure of the nucleus.

In solid bodies the atoms are packed in about one hundred million to the inch and the nucleus itself is about ten thousand times smaller in diameter. The atomic nucleus is the smallest thing whose structure is studied by man. The principal means of study has been by observation of what happens when atomic nuclei are struck by ions of hydrogen or helium which have been artificially accelerated to high speeds by means of high voltages. The bombarding ions need the high speed because they are charged positively and so are repelled by the nuclei, hence unless they have very high speeds they do not get close enough to produce any effect.

In the latter 1920's when physicists began to turn their attention to the nucleus, it was thought that several million volts at least would be needed to give the particles enough energy to effect nuclear transmutation. And at that time there was no known way that appeared practicable for getting more than one million volts. Cascaded transformers had been used up to one million volts or so. Electronic rectifiers in combination with transformers had been developed up to several hundred kilovolts. But then two developments occurred which opened up the subject. In the first place, theoretical applications of wave mechanics showed that the voltages needed were not nearly so high as at first thought. This theoretical prediction led to discovery that light elements could be transmuted with relatively low voltages—several hundred thousand—although at such voltages the yield is very low and rises exponentially with the voltage.

The other important development was the introduction of two means of getting particles of extremely high energy. These are the cyclotron of Professor E. O. Lawrence of Berkeley and the belt-type electrostatic generator of Professor R. J. Van de Graaff of the Massachusetts Institute of Technology. These made possible the production of high energy beams of positive ions for production of neutrons, artificial radio-active materials, and nuclear research in general. The principle of operation of each of these is well-known to this audience. In the cyclotron there are no extremely high voltages on different parts of the apparatus. Instead the ions are caused by a magnetic field to move in a spiral path while gaining energy from an alternating electric field. In the belt generator the high voltage is obtained by carrying charge to an electrode with an endless cloth belt. The maximum attained voltage depends on the breakdown strength of the dielectric around this high voltage design. This requirement leads at once to very large sizes and special means of insulation. Both types of equipment, when built on a scale sufficient to provide several millions of volts, are quite expensive—somewhere in the neighborhood of $100,000 being the amount needed.

The cyclotron started in 1930 with a very small model built by Lawrence, then a working instrument built by Lawrence and Livingston which gave 1 million electron volts (Mev.) protons. This was followed by another with a magnet having pole-pieces 37 inches in diameter which attained about 6 Mev. and last year by completion of another having 60 inch pole pieces which gives 16 Mev. deuterons and 32 Mev. alpha particles. Now Lawrence is busy with the details of a huge project involving a cyclotron with pole pieces 184 inches in diameter, the magnet of which will weigh close to 5000 tons, which will produce deuterons of some 150 Mev. energy. The project is estimated to cost in the neighborhood of $1,500,000 of which some two-thirds has been provided by the Rockefeller Foundation. In the same period there has been a very widespread recognition of the importance of this research tool as evidenced by the fact that there are some thirty cyclotrons in the world, either built or building, mostly in the United States, and mostly financed in the expectation that they will prove valuable research tools in medicine.

Going along with this story of steadily increasing voltage, the "cyclotroneers" have made an enviable record in improving the total beam current, the latest being a total of 300 microamperes of deuterons at 16 Mev. on the 60-inch cyclotron. This means practically 5 kilowatts of power in a form available for intense nuclear disintegrations. Just a few years ago we heard of currents of 0.1 microampere. Now currents well above 10 are commonplace and many cyclotrons are getting close to 100 microamperes of beam current.

The first large belt generator is the one built by Van de Graaff at Round Hill, Massachusetts. This attained very great voltages, around ten million, but the great difficulties associated with building a large vacuum tube in which to accelerate the ions with this generator were never successfully overcome. The tube was designed for horizontal operation, which introduced great difficulties of support. The first successful application of the belt generator principle to the study of nuclear physics is due to Tuve and Hafstad of the Carnegie Institution of Washington. Their generator with a two-meter sphere worked successfully to about 1200 kilovolts, and they usually have had available about 1 microampere of analyzed beam current. Later the Round Hill outfit was moved to the campus of the Massachusetts Institute of Technology and sat up in a different way to permit the installation of a vertical discharge tube. In this form it gets about 2500 kilovolts. This laboratory has principally applied the outfit to studies on the ultra hard X-rays produced when electrons of this voltage strike a metal target. Most X-ray physics and all radiological experience hitherto has stopped at 1000 kv., so we may hope for many interesting results from Cambridge.

About five years ago, Herb at Madison, Wisconsin, made the first really successful application of the use of compressed air as an insulating medium to improve the attainable voltage with a belt generator. Working with a pressure tank about 6 feet in diameter and 14 feet long, he built a machine which gives 2.5 million volts. The great gain in compactness which compressed air insulation gives is apparent when we realize that Herb's outfit in a small basement laboratory room gives essentially the same voltage as the large M.I.T. outfit which requires a good-sized building to house it.

With this experience to go on, the decision was made to build a large pressure insulated belt generator at the Westinghouse laboratories. This has been in operation about a year, as has also another similar one at the Carnegie Institution in Washington. Our machine is operated successfully at 4000 kilovolts with proton beam currents of about 1 microampere. The Washington machine has shown a similar performance. Two more pressure insulated belt generator outfits of intermediate size are now nearing completion, at the University of Minnesota and at the University of Pennsylvania.

I am sure that people who are closely interested in this subject would like me to say something about the relative merits of the two means of obtaining high energy particles. This is a quite complicated subject—and there seems to be no one who has had close working experience with both types. The Washington group soon will be in this position, for they are now building a large cyclotron like Lawrence's present large one to supplement the work of their large belt generator.

Since yields of neutrons or of radio-active materials go up roughly exponentially with voltage and directly with current, there is no question but that a cyclotron is at present superior to the belt generator as a strong producer of radio-active materials or of neutrons. And it does not seem likely that the belt type generator will catch up in total voltage and current for some time to come, so as a production instrument the cyclotron seems quite superior. In the belt generator the generator itself is capable of providing much greater currents—the crux of the problem is in the ion source at the high voltage end of the vacuum tube.

The main advantages of the belt generator seem to be as a scientific instrument and as a means of studying ultra-hard X-rays. The cyclotron cannot accelerate electrons owing to their light mass and high relativistic variation of mass. Moreover, the different particles in a cyclotron beam do not appear to be nearly so homogeneous in energy as the particles in the beam in a steady belt generator. In our outfit at Westinghouse, we feel the variation is scarcely more than ± one-tenth per cent, whereas I think all cyclotron beams show a range of about ± 10 per cent, although it is hard to get definite information on this point. This makes the belt outfit an ideal instrument for precision measurements of resonance levels in nuclei and for onset thresholds of certain endoergic reactions.

It appears, therefore, that the two machines are more complementary than competitive, and that each is destined to play an important part in the continuing development of nuclear physics.

Ornithology Laboratory Notebook

The first part of this notebook (pp. 1–54) deals with laboratory studies of topography and anatomy, classification, nests, and distribution of birds. The remainder consists of sheets for the study of individual species (pp. 55–156), field check lists (pp. 157–204), and 180 outline drawings of birds for coloring. The pages for individual species studies contain a map of North and South America, and space for notations on some 20 points about the species.

The changes in this edition are intended to make it more useful in other parts of the country than New York State. The keys have been enlarged to include all orders and families of North American birds, and 18 new outline drawings have been added. Some of the outline drawings are somewhat generalized and can be used for any of several similar species. Blank spaces have been added to the field check lists.

The evident emphasis in an ornithology course which follows this notebook is taxonomy and classification. The sheets for individual species are very detailed, and filling them out will probably become a chore rather than a learning process for the student. The value of the notebook would be increased by a simplification of these species sheets, and by the inclusion of some suggestions on field study and identification, ecology, censusing, plumages and coloration, and a bibliography.

The data given on distribution, which give the student an idea of what birds to expect in the field, and the excellent illustrated key to nests, are perhaps the two outstanding features of this notebook.

The fact that this notebook is now in its fourth edition is evidence of its usefulness in a course in ornithology.—*D. J. Borror.*

Ornithology Laboratory Notebook, by Arthur A. Allen. v+204 pp. Ithaca, Comstock Publishing Co. Fourth Edition, 1941. $3.00 (paper bound).

A COMPARATIVE STUDY OF NEUTRON- AND X-RADIATION UPON BIOLOGICAL TISSUES IN THE CANCER PROBLEM

ISADORE LAMPE, M. D.,
University Hospital, University of Michigan

The changes observed in irradiated biological tissues are believed today to be due basically to the ionization of tissue atoms. To the biologist and the radiation therapist, modern physics has presented many new ionizing sources in the form of artificially induced radioactivity in elements normally stable. All of these are of potential value in the field of cancer therapy.

At the present time interest is centered on the potential utility of fast neutrons in the treatment of cancer. More extensive investigations on normal and abnormal biological tissues have been carried out with fast neutrons than with any of the other products of research in the field of nuclear physics. Although the results of these studies are of interest to biologists in diverse fields, to those engaged in the treatment of cancer, there exists one primary question. Will neutron radiation be more effective than X-rays in the treatment of cancerous diseases of the human organism?

In studying the biological effects of neutrons, many investigations previously performed with X-rays have been repeated with neutrons. The results of these studies reveal the essential qualitative similarity of tissue reactions to neutrons and x-rays. Several workers have shown that neutron irradiation increases the rate of mutation formation in fruit-flies (*Drosophila melanogaster*) (1, 2); geneticists have employed x-rays for this purpose for many years. Certain phases of the process of mitosis (which determines cell division and therefore tissue growth) can be suppressed both by neutron and x-ray irradiation (3, 4).

The embryological development of Drosophila eggs is disturbed in the same fashion by x-rays and neutrons. The larvae surviving both types of irradiation demonstrate aberrations of organ development(5). Both radiations suppress the growth of wheat seedlings and inhibit cell division of the fern spore.

Experiments carried out on mammalian tissues demonstrate that identical changes are produced by both radiations. Whole body irradiation of mice with neutrons and x-rays produces death of the animals; the blood-forming tissues, the lymphoid tissues and organs, as well as the lining cells of the intestines are damaged or destroyed (6). The characteristic changes seen in the blood cell picture of animals irradiated with x-rays is found with neutron irradiation. Experiments with transplantable mouse cancers have shown that suppression of the growth of the tumor transplants is brought about by both radiations (7).

More recently with the development of collimated neutron beams, the reaction of skin to neutrons has been observed in rabbits and in man. The changes appear to duplicate those following x-ray irradiation.

Thus the effects of neutrons have been observed in a variety of biological processes: mutation production, suppression of mitosis, inhibition and impairment of embryological development, suppression of cell division and of growth of tissues; the destructive action of this radiation on mammalian tissues has been demonstrated. In each instance it seems that, in kind, the changes are of the type seen following x-ray irradiation.

Certain quantitative aspects of neutron ionization merit consideration. Early in their work Lawrence and his associates found it convenient to measure neutron ionization with the same small ionization chamber as is used currently to measure x-ray ionization (8). The work of Gray on the measurement of gamma ray energy indicates that under certain conditions the use of such chambers for measurement of neutron ionization is valid (9). When used with x-rays, the scale units represent roentgens, the international unit of ionization quantity; when used with neutrons, the same unit deflection has been arbitrarily termed the n-unit.

The relationship of the quantities of ionization in tissue that the two units represent has not been definitely determined as yet; this is a matter of considerable importance. By irradiating fern spores with alpha particles Zirkle demonstrated that the biological effectiveness of the radiation was greatly influenced by the ion concentration along the path of the ionizing particle; the biological effectiveness varied approximately as the 5/2 power of the ion concentration (10). In view of the greater concentration of ions along the tracks of protons and other recoil particles produced by neutron irradiation, a greater biological effectiveness was to be expected for neutrons than for x-rays.

A number of comparisons on various biological test objects have been carried out by Lawrence and his associates (7, 11) and also at the University of Michigan (12); it was found that in apparently every instance neutrons were more effective than x-rays in producing equivalent biological reactions. The differences in efficiency ranged from a factor of 2 in inhibiting hatching of Drosophila eggs to a factor of almost 12 in suppressing organ growth in wheat seedlings.

Although these figures cannot be accepted at face value until the relationship between the two units of ionization has been clearly established, there is indirect evidence to indicate that the greatest possible error probably does not exceed forty per cent (12).

In an interesting report, Zimmer and Timofeeff-Ressovsky have shown that neutrons are less effective than x-rays in affecting the mutation rate of Drosophila (1), and have demonstrated that, since mutation production depends on the formation of one ion pair in a gene, a decrease in effectiveness should be obtained with the type of distribution of ions created by neutron irradiation. For those biological reactions which require the formation of multiple ion pairs in the so-called "sensitive" volume, the distribution of neutron ionization should be more effective than that obtained with x-rays.

It appears then that in neutrons we possess not only a radiation which produces changes similar to those seen with x-ray irradiation but a radiation which is apparently of greater effectiveness in exciting reactions of the kind we are concerned with in the treatment of cancer.

This radiation probably will be more lethal than x-ray in its action on the cancer cell but does this mean that it will be more effective in treating cancer in the human body?

In order to be effectively employed, a radiation must act in a selective fashion: the tumor must be destroyed but the regional normal structures must be preserved. It is because of the existence of such a favorable differential action on cancerous and normal tissues that x-rays and gamma rays have attained a measure of success in the treatment of malignant neoplastic diseases. Other factors being equal, neutron radiation will be more effective in the attack on cancer in the human organism if its differential action is found to be more favorable than that of x-rays. The absolute biological effectiveness is only of secondary importance.

Because collimated neutron beams were not available until recently, it was necessary to approach the problem of the differential or relative actions of x-rays and neutrons in an indirect manner. From a broad biological viewpoint a cancer and its regional normal tissues represent related tissues in the same organism and the basic problem devolves to a consideration of the comparative action of neutrons and x-rays upon two such tissues.

In the first investigations by Lawrence and his associates, a number of different types of biological test objects were used: Drosophila eggs, fern spores, transplantable mouse tumors, mice, and wheat seedlings (7, 11). It was found that the relative effects of the two radiations upon these organisms presented decisive differences. Had these experiments indicated that the relative effects of the two radiations upon such diverse types of biological tissues were consistently the same, certainly it would have appeared highly improbable that a remarkable difference could be expected for two tissues as closely related as cancerous and normal cells in the human organism.

In order to create a situation in which the relative effects of the two radiations could be studied on tissues as closely related as a tumor and its regional normal structures, Drosophila eggs were irradiated at different stages in their development (12). Here again though dealing with two sets of tissue in the same species of organism, significant differences were found. By irradiating wheat seedlings, the relative action of the radiations upon different organs (root and shoot) in the same individual organism was investigated and despite the essential similarity of the tissues composing these organs, the relative effects of the two radiations were found to be consistently different.

On the basis of the demonstration that differences in the relative action of neutrons and x-rays exist not only for distantly related but also for closely related biological tissues, it appears highly probable that a difference in the relative action of the two radiations upon cancerous and normal tissues may exist. The selective action of neutrons probably will differ from that of x-rays. As yet no evidence exists to indicate whether the selective effect will be more favorable or less favorable than that of x-rays; it is evident that this represents an incomplete solution of the problem. At the present time, at the University of California and to a lesser extent at Michigan, several collimated neutron beams are being used in a direct attack upon the problem; a more adequate estimate of the potential usefulness of neutrons in cancer treatment may become available in the near future.

BIBLIOGRAPHY

(1) **Zimmer, K. G.,** and **N. W. Timofeeff-Ressovsky.** Dosimetrische und strahlenbiologische Versuche mit schnellen neutronen II. Strahlentherapie, 63: 528–536, 1938.

(2) **Nagai, M. A.,** and **G. L. Locher.** The production of mutations in Drosophila with neutron radiation. Genetics, 23: 179–189. 1938.

(3) **Marshak, A.** Effect of fast neutrons on chromosomes in mitoses. Proc. Soc. Exp. Biol. and Med., 41: 176–180. 1939.

(4) **Spear, F. G., L. H. Gray,** and **J. Read.** Biological effects of fast neutrons. Nature, London, 142: 1074–1075. 1938.

(5) **Enzmann, E. V.,** and **C. P. Haskins.** Note on modifications in the morphogenesis of *Drosophila melanogaster* occurring under neutron bombardment. Amer. Nat., 73: 470–472. 1939.

(6) **Lawrence, J. H.,** and **R. T. Tennant.** The comparative effect of neutrons and x-rays on the whole body. Jour. Exp. Med., 66: 667–687. 1937.

(7) **Lawrence, J. H., P. C. Aebersold,** and **E. O. Lawrence.** The comparative effects of neutrons and x-rays on normal and neoplastic tissue. Occas. Publ. Am. Ass. Adv. Sci., No. 4: 215–219. 1937.

(8) **Lawrence, J. H., P. C. Aebersold,** and **E. O. Lawrence.** Comparative effects of x-rays and neutrons on normal and tumor tissue. Proc. Nat. Acad. Sci., 22: 543–557. 1936.

(9) **Gray, L. H.** An ionization method for the absolute measurement of gamma ray energy. Proc. Roy. Soc. London, Series A, 156: 578–596. 1936.

(10) **Zirkle, R. E.** Biological effectiveness of alpha particles as a function of ion concentration produced in their paths. Am. Jour. Ca., 23: 558–567. 1935.

(11) **Zirkle, R. E., P. C. Aebersold,** and **E. R. Dempster.** The relative biological effectiveness of fast neutrons and x-rays upon different organisms. Am. Jour. Ca., 29: 556–562. 1937.

(12) **Zirkle, R. E.,** and **I. Lampe.** Differences in the relative action of neutrons and roentgen rays on closely related tissues. Am. Jour. Roent. and Rad. T., 39: 613–627. 1938.

Magnetism and Very Low Temperatures

Magnetism and Very Low Temperatures, by H. B. G. Cassimir is a tract based on a series of lectures delivered by the author at Cambridge in the spring of 1938. The treatment is contained in seven chapters of which the first is introductory in character. The second chapter is devoted to classical theories and experimental methods. In chapter three the author presents a brief and concise treatment of the essentials of the quantum theory of paramagnatism. Chapter four is devoted to the experiments on adiabatic demagnetization and in chapter five the author gives a theoretical discussion of paramagnetism at low temperatures. Chapter six is given over to experimental results and finally in chapter seven is discussed the relaxation phenomena.

Like many others of the tracts in this series of publications the material is presented in a very comprehensible manner. It is presented on a level which can be digested by graduate students with an intermediate training and gives the reader a good insight into the problem of magnetism and very low temperatures.

—*H. H. Nielsen.*

Magnetism and Very Low Temperatures. H. B. G. Cassimir. Pp. 93+ix, Fig. 14. Cambridge, At the University Press, 1940.

CANCER: CLINICAL AND EXPERIMENTAL ASPECTS

FRANCIS CARTER WOOD, M.D.,
Director of Cancer Research Institute,
Columbia University

Since civilized man recorded his opinions on stone, papyrus or in the memories of man, cancer has been mentioned. The early Greeks, Hindus and Egyptions left recognizable descriptions of what they saw. It is probable when the Stone Age man noted his wife dying of something which he could not understand that it was a cancer. Crude surgery developed during the Middle Ages, but presumably no one was ever cured. The invention of the microscope was the next necessary step and then came the discovery of the cellular nature of the tissue structures about one hundred years ago. In the forties and fifties of the last century the classification of human tumors became the main subject of interest. Various hypotheses as to the causation of cancer were produced, the most important being that of Virchow, who believed that the appearance of cancer was usually correlated with chronic irritative processes, and clinical observers began to collect material to support this notion. The betel-nut cancer of the mouth in the East, and the Kangri cancer due to the native custom of carrying a basket of burning charcoal under the clothes for comfort in winter, which frequently burned the abdominal wall, are two examples. Many of these burns were followed by cancer. The Far East also offered the first examples of the parasites in the internal organs which ultimately cause human cancer. About 1875 Cohnheim introduced the idea that many of the more complex growths were the result of remnants of tissue left during embryonic development.

Attempts to transplant tumors occurring in domesticated animals were carried on for many years but failed completely until Loeb and Jensen at about the same time, that is in 1901 to 1903, found that spontaneous tumors in mice and rats were transplantable into the same species only. Shortly after this the Imperial Cancer Research Fund was established in England, with Bashford at its head. He was an aggressive, broadly trained pathologist and gave great impetus to cancer research. Another worker was the famous Paul Ehrlich, the inventor of salvarsan, who after a few years abandoned all attempts at cancer research but made important contributions concerning inoculated tumors during this period. The earliest studies were exploratory in direction and included the transplantation of tumors in animals purchased, in general, in the open market, and the observation of a host of phenomena following grafting, among them the prompt disappearance of a tumor, leaving the animal immune.

This false lead has wasted hundreds of thousands of dollars and literally thousands of years of labor. For thirty years investigators had been struggling to imitate the process of the spontaneous disappearance of tumors. Finally, Little, a geneticist, Tyzzer, a pathologist, and the workers in the Institute of Cancer Research of Columbia University, began to insist upon the importance of pure strains as a culture medium for the tumors. Immediately all spontaneous cures ceased, no immunity could be produced by the inoculation of tumors, and a host of observations, biologically important but not pointing the way to any fruitful results, have disappeared into the scrap-basket of the forgotten.

It is now generally understood that the cancer cell is an individual in the body of the host and that some tumors may spring from a single cell. More rarely multicentric growths appear. It probably takes an individual cell a long time before it and its descendants make a sufficient mass to produce a noticeable tumor, years in fact in man and more rapidly in the shortlived rodents. The change in the cell is probably a mutation of some type or if the geneticists want to argue about the question of a "somatic mutation," let us leave the phrase to them and call it a change of some sort in the protoplasm and the nucleus of the cell. Once this change has taken place the new race lives as a parasite on the body of the host. There is ample evidence now that this is a permanent and irreversible change. A cancer cell cannot be made to revert to a normal cell, as was believed even a few years ago.

All the morphological and biological qualities of these inoculated tumors remain permanent over thousands of transfers. The Jensen rat sarcoma still looks as it did in 1903. Nevertheless, this new race has the same cell chemistry of the host in which it originated and, therefore, it does not incite reactions of the type induced by bacteria and foreign proteins. Hence, the search for immune reactions has been a continuous failure.

It was hoped that cancer could be diagnosed by serum or chemical reactions, but all efforts have so far failed, with the exception of the Aschheim-Zondek test. This is limited to one type of tumor and is based upon the stimulation of the ovary of the mouse or rabbit to form a hemorrhagic follicle owing to the production of hormones by the tumor. The source of these hormones are the chorionic cells from the placental structures which form in the teratomas of the testicle. The use of the Aschheim-Zondek test is not so much to make a diagnosis of the teratoma as to call attention to recurrences if such take place, as in that event the patient can be treated by x-ray. The seminomas of the testicle, the most frequent type of tumor, do not show any reaction to the Aschheim-Zondek test, as their cells are derived from the testicular tubules. In women with chorio-epithelioma of the uterus, a positive reaction is important if pregnancy can be excluded and if the reaction does not become negative, it shows that extensions of the growth have taken place in other parts of the body where they may be unrecognizable even by x-ray examination.

It was hoped also that in some way we might extract anti-bodies from animals with cured cancer which, when injected into a cancerous animal or a cancerous human being, would result in the destruction of the tumor. All this failed. A large series of experiments was carried on by Hodenpyl, who used the ascites fluid from a case of quiescent human cancer to inject numerous patients, with results which were startling at the time, but unfortunately no cures resulted. The injection of damaged cancer cells, killed by heat, cold, radiation and chemical agents, was tried in the hope of inducing an immunity similar to that obtained by injecting dead bacteria, but without the slightest result.

It has been known for nearly 200 years that gas tar causes cancer in human beings. For a long period attempts were made to produce cancer in animals by this agent but, curiously enough, the experimenters used either dogs or white rats and the skin of these animals is not susceptible to this agent. If they had used white mice they would have succeeded in the first attempt, because the skin of the mouse is exceedingly sensitive to tar irritation. Yamagiwa, in 1915, showed that cancer could be produced in the ears of rabbits by tar painting. Many of these were only papillomas, but a moderate number of carcinomata can always be produced with an effective tar. The English, who are always interested in tar and the industrial oils because of the large number of cases of carcinoma which occur in their factories, continued these investigations and the most promising were those of Leitch and Kennaway. Kennaway showed, in 1925, that acetylene when heated yielded a cancer-producing tar, hence the substance which causes cancer in tar workers would probably be of that composition, that is carbon and hydrogen.

The spectroscopic study of many of the carcinogenic substances showed a characteristic fluorescent spectrum in the near-ultraviolet, and Hieger showed that 1 : 2 dibenzanthracene gave this same spectrum. Clar in Germany was the first to synthesize 1 : 2 : 5 : 6 dibenzanthracene and Cook, who was working with Kennaway, resynthesized this material and found it to be carcinogenic. A somewhat more powerful carcinogenic substance was obtained from gasworks tar and is known as 3 : 4 benzpyrene. In 1933, another carcinogenic substance, methylcholanthrene, was synthesized by Wieland and Dane. Cook investigated this compound and found it highly carcinogenic. Methylcholanthrene is derived from the cholic acids and this suggests the possibility that such a synthesis may take place in the body. Further studies have shown that beta-naphthylamine given by mouth or subcutaneously will cause tumors of the bladder and Japanese workers have produced tumors of the liver with orthoaminoazotoluene and paradimethylaminoazobenzene. Azotoluene causes cancer of the bladder and it is probable that 3 : 4 : 5 : 6 dibenzcarbazole produces not only cancer of the skin at the site of application but also tumors of the liver.

The method of action of these compounds is unknown and tumors have been produced in a variety of animals: mice, rats, rabbits and guinea pigs. Tests are going on with the longer-lived creatures, but the ape, for instance, which presumably has a life of some twenty or thirty years, would require three or four years' treatment to produce a tumor. For out of all these studies has arisen the fact that the time of appearance of a tumor with the same carcinogenic agent is correlated with the length of life of the animal. If a mouse lives two years, one-twelfth of that would be two months; if a human being lives 72 years, one-twelfth would be six years. It would be expected that if a mouse had a tumor in two months, which is the case, the human being might require six years, and such is also the case in connection with tar workers, x-ray injuries and a number of other cancers the origin of which we can determine.

Another experimental study has been the investigation of the effect of trauma on animal tumors in order to determine the possibility of a single injury causing cancer in human beings, a matter which is frequently discussed in the law courts. All the animal experiments showed that trauma had no effect on a tumor.

The three most important practical investigations which have come out of the laboratory are: (1) The demonstration by Tyzzer and Knox, that the massage distribution of animal tumors with small cells can be easily accomplished, while the fibrous types, such as the fibrosarcomata and some of the sarcomata with large cells could not be dislodged by massage, and the small-cell sarcomata metastasized extensively without massage. (2) It was shown that the incision of a tumor for removal of a specimen for microscopic examination was not injurious in animals when properly carried out. (3) Quantitative experiments using radium and x-rays on tumor particles and tumors in animals showed, twenty or more years ago, that animal tumors required large doses to destroy their cells, an important bit of knowledge which is just beginning to penetrate into human practice and reveals the lag between the laboratory and the clinic.

It is obvious that the laboratory research side has been in general more the laying of foundations and the removal of misconceptions, most of which were derived from bacteriological analogies. The investigation of cancer has really gained nothing from bacteriology. General biology, on the other hand, has greatly benefited by the discoveries of Rous, Gye, Shope and other workers who have studied the cancer problem from the point of view of the viruses. This does not mean that human tumors are with any probability connected with virus infections, but the fact that certain chicken sarcomas are is an important biological point and the recent demonstration by Rous that the Shope rabbit papilloma virus can act as an agent for the production of malignant growths in the rabbit by means of tar or the carcinogenic hydrocarbons was certainly a discovery of prime importance as regards general biology.

The real advances, however, which have been made in the last forty years on the cancer problem have not been made by the laboratory investigators. They have rather been due to mass attack on the problem and two vital discoveries in physics, that of the x-rays by Roentgen and of radium by Marie Curie. They have added immensely not only to diagnosis but to the treatment of cancer as well. It is scarcely necessary to mention before this audience what enormous facilities have been placed in our diagnostic armamentarium by the development of the x-ray technic. No one procedure in diagnosis has been so valueble in every phase of medicine and surgery as this.

Other improvements have taken place, all of them practically within the last forty years. Firstly, the development of asepsis, which was really concluded with the adoption of the rubber glove, in about 1895. Then there is anesthesia, which, of course, is always necessary for the prolonged surgery of cancer. Not only general anesthesia with ether, but also a host of modern anesthetics, both general and local, greatly facilitated the handling of the disease in surgery. Forty years ago the treatment of cancer was in the rudimentary stage and very few patients were ever permanently cured or relieved of the disease. Today with the introduction of improved instruments, such as the gastroscope, bronchoscope, cystoscope, peritoneoscope, etc., the various internal organs of the body can be inspected and tumors can be seen and fragments removed for microscopic examination. While it is not always possible to see every carcinoma of the stomach or every bronchial carcinoma, nevertheless most of the tumors of these regions, even of small size, can be demonstrated.

Since 1895, a matter of only forty-five years, the whole development of an effective attack on cancer has taken place. This is due largely to experimental work on animals and the efforts of leading surgeons in this country and Europe. What we have learned from experimental physiology and pathology has in many ways directly helped in the traetment of cancer and added to our ability to attack the disease in parts of the body where no one had thought of attempting to do so with successful results ten years ago, yet such operations are now being done quite frequently, as in the case of carcinoma of the lung. Obviously, many of the internal cancers are seen so late that despite modern diagnostic efficiency nothing can be done because metastases have occurred throughout the body. But with the improvement in and extension of education which, of course, must go hand in hand with diagnosis, patients are coming earlier for examination and many are having annual or semi-annual studies made in order to eliminate the possibility of an inaccessible growth.

A good deal of this effort owes its success to the publication of large series of cases operated upon or treated by radiation which have survived for a five or ten year period. The American College of Surgeons has contributed much to this by the collection of some 30,000 recorded cases of cancer well for five years or more. This was done very easily, the figures coming mostly from the large hospitals in this country, and such a demonstration cannot help but be impressive and of value in aiding education. No one will listen with pleasure to a recital of the number of deaths from cancer. On the other hand, now that the profession is in a position to say that as a result of the last forty-five years' work and scientific study a real step forward has been made, people will listen eagerly.

An example of the change which has come has just been published by Schinz from the Radiation Clinic in Zurich, giving a complete review of their material as observed from 1919 to 1935, with no selection whatever. In this period 2529 patients were treated. In January, 1937, 15 per cent of the total were alive and apparently well. There could be added to this 2 per cent more who died from intercurrent disease during the period without symptoms of cancer, but they and the untraced cases, amounting to another 2 per cent, were rejected. Also, favorable palliative results were obtained in 54 per cent of the total. The patients referred to this Clinic are most of them inoperable and, therefore, represent a more or less hopeless group and the fact that 15 per cent of these hopeless cases can be cured now by radiation, when twenty years ago the effective use of x-ray was just beginning and probably all these patients would have died, shows what can be accomplished.

Another field in which there has been great improvement is that of cancer of the cervix. The League of Nations figures are astounding. Studies of many thousands of cases have been made from all over the world and about one-fourth of such patients are cured for five years or more. The interesting point in this is that the conditions are not very favorable for early diagnosis and in those cases in which the diagnosis was made early, there was a 40 to 50 per cent of five-year cures. But more important still is the fact that there were 5 per cent of cures in the hopeless and advanced types which have never been cured by surgery.

On the other hand, from a purely surgical standpoint, cancer of the breast is now being cured in about 30 to 35 per cent of all patients coming to the hospital for treatment and the early types are being cured in 75 to 80 per cent. This means that the tumor has been diagnosed microscopically and the patient has been followed for the elapsed five years.

This is an astonishing thing to one who like myself has watched the whole period of development of cancer surgery and radiation. During the time of my internship, for instance, from 1894 to 1897, only the very smallest and earliest superficial tumors were cured and no attempt was made to cure a cancer of the stomach, for example, of which the Mayo Clinic now reports a 5 per cent salvage. Most of our patients came so late that the operations today would not be undertaken. Now when a patient is considered inoperable, he is treated palliatively with radiation or surgery, or both, to prolong life as much as possible in comfort.

Principles of Genetics

It is indeed unfortunate when an otherwise excellent book is marred by a few gross misstatements of fact. Such is the case of the recent book, "Principles of Genetics," by Grace White. In man the inheritance of the blood groups is known to be due to triple alleles. No trait in man is more clear cut or more definitely established, yet the author states that the inheritance of the blood groups is due to duplicate factors.

On page 265 we find the following statements: "The chances for any one autosome from a paternal grandparent reappearing in a grandson is estimated at $1 : 2^{23}$ or one chance in 8,388,608. The grandson has one chance in six, however, of receiving the paternal grandparents' X-chromosomes, and this makes the study of sex-linked inheritance far simpler than the study of autosomal characters." These statements are obviously incorrect. There is no chance whatsoever that a boy received his X-chromosomes from his paternal grandfather. Moreover, the chances that he did *not* receive *any* autosomes from his paternal grandfather are 2^{23}, quite different from the author's statement. Sex-linked factors may be detected more easily in males because the recessives manifest themselves when present.

The book as a whole is very readable, and is written in an interesting manner. Mutations are used in the broader sense, to include chromosomal aberrations as well as gene mutations. The illustrations are both excellent and numerous. Aside from the errors mentioned above, the book is an unusually good elementary treatise of genetics.—*D. C. Rife.*

Principles of Genetics, by E. Grace White. 352 pp. St. Louis, The C. V. Mosley Co., 1940. $2.50.

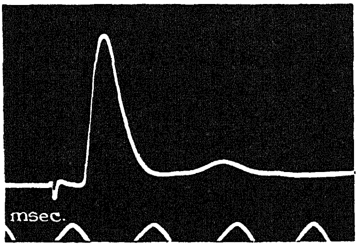
THE CLASSIFICATION OF NERVE FIBERS

HERBERT S. GASSER,
The Rockefeller Institute for Medical Research,
New York

As more is learned about the mechanism of operation of the central nervous system, the characteristic of the mechanism that becomes the most impressive is the exquisite timing of the events. For example, if an impulse of subliminal effectiveness impinges upon a synapse, it leaves a trace which lasts only a few tenths of a millisecond. If within that time another impulse, likewise of subliminal effectiveness, arrives at the same region on the surface of the neuron, the two impulses together will raise excitation to the threshold, and a relayed message will be sent upon its way. Stated in other words, if the two impulses arrive at the synapse at an interval of separation longer than a few tenths of a millisecond, there is no transmission; and the local disturbance that each impulse produces dies out promptly, to leave the junctional area restored to its antecedent state ready for any new impulses that may be coming on. Transmission at any point thus depends upon the arrival of excitation from the various controlling centers in exactly the right time relations. Thereby the flow of impulses is always properly directed toward the end reaction appropriate to the conditioning data picked up by the body receptors.

The timing of impulses starts in the beginning of all reactions—in the sensory messages that report changes in the state of the body and in the character of the environment. At least no other interpretation explains as satisfactorily why sensory messages are carried at so wide a range of velocities. For some reason not at all well understood it is necessary for some impulses to shoot out ahead to prepare the central nervous system for other impulses that arrive later. In as simple an event as pricking the skin of the finger with a needle there is first a short burst of impulses carried in fibers conducting at 90 meters or more per second (20). Then there follow impulses at other velocities, many at about twenty meters per second; and finally there is a trail of impulses at about one meter per second. Before any of the last mentioned group arrives at the centers, a complex neurological event has taken place—the withdrawal of the hand; and the sensation of pricking has been appreciated. The sensation aroused by the slow fibers is still, however, that of pain indistinguishable qualitatively from the pain already felt. But in its setting it has a stinging, irritating character. It can be relieved by rubbing the spot, that is, it may be inhibited by sending into the central nervous system a flood of impulses carried in rapidly conducting fibers.

It is not my intention in the present paper to follow up this argument, but to let the observations stand as an introductory background to the main theme, which is the basis of the numerous velocities in nerve fibers. Visualization of the wide range of velocities can best be accomplished by showing what happens when a sensory nerve is artificially stimulated with an electrical shock of short duration. All the impulses start out together from the locus of the stimulus, but the fast impulses forge ahead. Thus, if a lead be taken at some distance from the point of stimulation, at the beginning of the action potential there are initially recorded the first impulses to arrive; and the other impulses are recorded later, at times inversely proportional to their velocities. As all the velocities are not equally represented among the fibers, the result is an action potential with distinctive elevations. The contour here presented (Fig. 1), taken from the saphenous nerve of the cat, is characteristic of all sensory nerves. It starts with a high elevation contributed by fibers conducting at velocities ranging approximately between 95 and 35 m.p.s. The high elevation is succeeded by a very small one in which velocities between 35 and 22 m.p.s. are represented; and this in turn is followed by a somewhat larger one representing velocities between 22 and 15 m.p.s. In the wake of the latter there are still a few impulses at a velocity slower than 15 m.p.s.



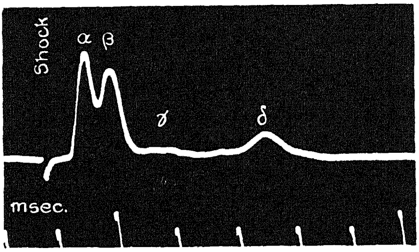


Figure 1 (left). Action potential of the saphenous nerve of the cat as recorded after 4 cm. of conduction from the stimulating cathode. The first disturbance in the line marks the moment of stimulation, and the interval between this point and the start of the first high elevation measures the conduction time of the fastest fibers. The potentials contributed by the other fibers follow in succession.

Figure 2 (right). Action potential of the saphenous nerve of the rabbit as recorded after 4 cm. of conduction.

The first elevation is actually a fusion of two elevations, as can be shown in leads at long conduction distances, or more easily in the nerves of young animals (Hursh), or in the saphenous nerve of the rabbit (Fig. 2). For the sake of ease of reference, the elevations have been given names. The terminology has undergone a series of revisions in the course of its historical evolution, and it is not entirely satisfactory. Subject, however, to the definition here given, it seems well to adhere to the original designations in terms of the Greek alphabet; and the elevations are accordingly called alpha, beta, gamma, and delta. Collectively the fibers so designated are spoken of, for reasons that will appear later, as the A group. The group takes in all the medullated fibers of somatic nerves. The remaining, unmedullated fibers are included in the group known as C. In order to visualize the potentials in C fibers it is necessary, because of their small size, to resort to much higher amplification than is necessary for the A fibers; and because of their slow velocities, to much lower sweep speeds, (Fig. 3).

After this preparation we are ready to penetrate further into the velocity problem. At the outset it may be stated that the size of the fibers is to play a large part in the argument. The first association of velocity with fiber size was made by Göthlin in 1907, long before the advent of the modern vacuum tube era in electrophysiology, and at a time at which knowledge about velocities was in a highly fragmentary state. Göthlin's contribution is to be recalled merely because of its inherent fundamental idea, as his treatment was a theoretical one based upon the structure of axons and the Thomson cable equation, and his deductions are not in accord with the facts about conduction as they are now known. The association of nerve function and fiber size again appeared independently four years later in the work of Lapicque and Legendre. What these investigators actually did was to measure chronaxies and correlate them with the axon size, and their statement that the velocity in the fibers was in direct relationship with the size was purely an inference. As it has turned out, it has been proven that the inference was correct, but that the chronaxie-size relationship had to be abandoned. Blair and Erlanger in 1933 demonstrated that the chronaxie of frog fibers is almost constant in the velocity range between 7 and 30 m.p.s.; and Lapicque, as the result of some experiments performed with Pézard, has now modified his view and gives prominence to his older idea that chronaxie is a parameter of the protoplasm of the fibers.

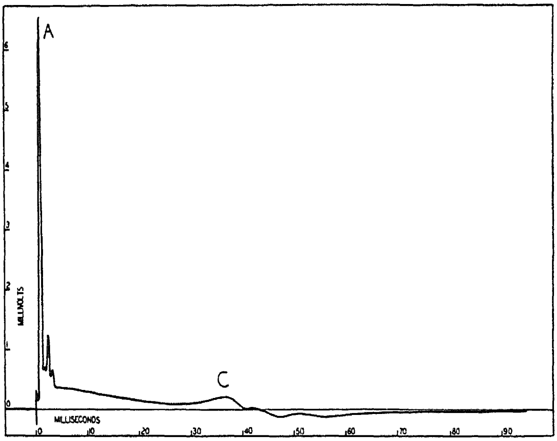


Figure 3. Drawing of the action potential of the saphenous nerve of the cat, constructed from two records made at different amplifications and sweep speeds. Activity of all the fibers is shown. The A complex depicts activity in the same group of fibers represented in Figure 1 (but from a different nerve). The interval between the A and C elevations is filled in by the negative after-potentials of the A fibers.

In 1924 it was my good fortune to be working in Prof. Lapicque's laboratory at the Sorbonne. At that time the observation that Erlanger and I had made of the temporal dispersion in the action potential of nerves was very recent, and when I showed the records to Prof. Lapicque he immediately said that the velocity variation at the root of the dispersion must be attributable to fiber-size variation. Thereupon we proceeded to test the hypothesis (14). Because of the supposition that chronaxie might be related to the cross-sectional area of the axons, which was incorrect although we did not know it, we tried first to correlate velocity and area, but with no success whatever. Then we tried the first power of the diameter and the result was much more promising. At this time the work was interrupted by my return to St. Louis, and it was there taken up again with Dr. Erlanger.

Before going further it will be necessary to say a word about the method employed. The first step was to record the action potential at a known distance of conduction. Then the nerve was sectioned and a distribution map of the fiber diameters prepared. The velocity of the fastest fiber, which could be read from the record, was assigned to the largest fiber and the velocities of the other fibers were calculated therefrom on the basis of the diameter ratios. There was experimental evidence to show that the spikes all had the same duration and it was calculated that the recorded heights of the spikes should be as their cross-sections. Accordingly, the further procedure was to calculate the potential that fibers of each size should contribute to the compound action potential, plot the result as spikes at the conduction times determined by the velocities, add the spikes together, and compare the sum with the action potential as actually recorded. The resemblance of the reconstructed and the recorded potentials was remarkably close, and it was felt that at least a first approximation to the size rule had been found.

But, whatever there was of satisfaction was only that which the ignorant can enjoy. And it was short-lived. The situation may be compared to the knowledge of geography before America was discovered. Our fiber world ended at gamma, with an uncertain and nebulous delta in sight beyond it. As soon as high gain amplifiers were built it was possible for us—that is, for Dr. Erlanger and myself—to see that there were two well-defined elevations that had not previously been recognized, those now labeled delta and C. With the finding of these elevations the fiber problem became wide open again. Reconstructions made under the rules gave so inadequate a fit with the recorded action potential as to indicate that something was wrong. Indeed, it was even doubtful whether the method was applicable at all, as it could be expected to work only within a homogeneous group of fibers. A new question was raised: How many kinds of fibers are involved? The natural inference was that there were three kinds. But there was difficulty in connection with the second elevation, which was then labeled B and is now labeled delta in mammalian nerves. The fibers in the B elevation in frog somatic nerves were obviously not homologous with those in the mammal. A solution of the difficulty came through a parallel study of visceral nerves made by Bishop and Heinbecker.

These investigators delimited the B elevation in visceral nerves and showed through estimations of the spike durations and the refractory periods that the constituent fibers are different from those in the C elevation and in the alpha portion of the A elevation. In the frog the B fibers pass through the grey rami into somatic nerves, but they do not do so in the mammal. The fibers which produce the elevation, then labeled B, in the action potential of mammalian somatic nerves were shown to have properties much closer to those of the fast A fibers than to those of the B fibers of visceral nerves. Thus, if they really were different from A fibers, a separate, fourth class had to be defined.

Without important additions or changes the formulation remained as here stated until 1933, when Blair and Erlanger introduced a radically new idea. On the basis of data obtained upon single frog-axons, which indicated that from the fastest fibers down to those conducting at one meter per second there is a progressive increase in the duration of the spikes and the refractory periods, these investigators proposed that the fibers make up a continuously varying series; and they felt that the division into groups was unjustifiable.

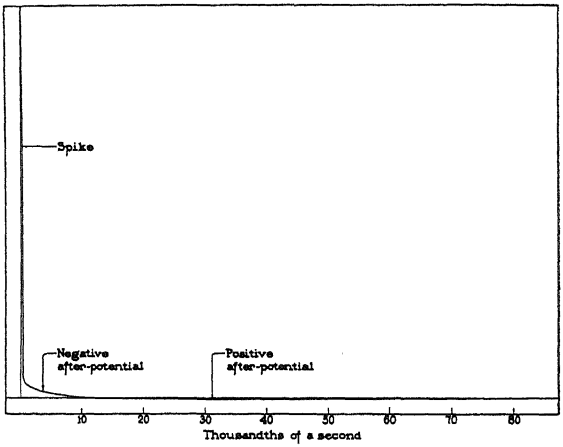
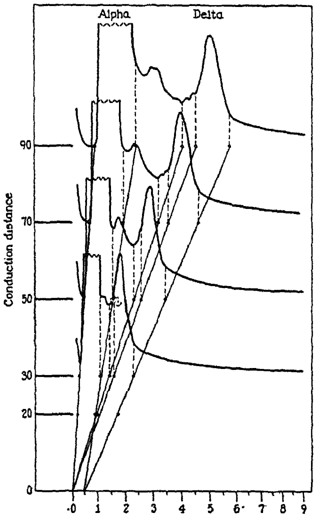


Figure 4. Course of the whole potential cycle in a unit mammalian A fiber, drawn to scale from two records made at different amplications and sweep speeds. It can be seen from the almost invisible size of the positive after-potential in this drawing that much higher amplification is needed to reveal the after-potentials than is needed for the recording of the spike.

In the past few years our laboratory, for two reasons, has taken a renewed interest in nerve fibers. The first and foremost reason was that there was a need for more precisely determined constants of mammalian fibers as equipment for the interpretation of the events that take place in the central nervous system. The second reason was to prepare the way for a return to the old problem of velocities. With the new information there came new tests for homogeneity. Previously the classification of fibers had depended largely upon the properties of the spike. But the spike is only part of the action potential. The whole action potential is made up of three parts: first the spike, then a negative after-potential, followed by a positive after-potential (Fig. 4). The after-potentials are even more typical of the fibers than the spikes.

Every precaution was taken to keep the nerves in the best possible physiological condition. Unlike the spikes, which are very stable, the after-potentials are extremely labile. Environmental changes alter both their form and duration; therefore, they are very sensitive indicators of the state of the nerve. With this lability it may perhaps be asked how one can know what the normal is like. The answer is the following. The after-potentials determine a cycle of excitability, and if the form of the after-potential corresponds exactly to the excitability as determined on the same nerve *in situ* under its natural perfusion of blood, there is every reason to believe that the fibers are normal.



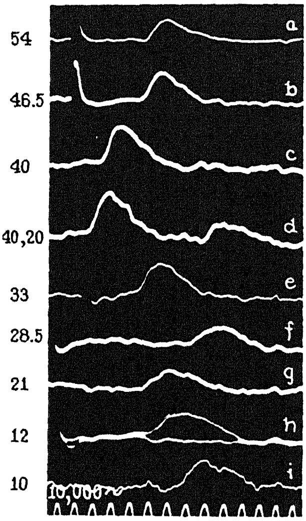


Figure 5 (left). Action potentials in the sphaenous nerve of the cat recorded at the distances indicated on the ordinates. Because of crowding in the figure, only the projection of the events on the base line is shown at 2 cm. of conduction. The time interval subtended by the converging lines at the axis of abscissas measures the duration of the alpha and delta spikes. (Gasser and Grundfest, 1939.)

Figure 6 (right). Unitary axon spikes arranged according to velocity (simultaneous responses in 2 fibers in record i). The velocities are marked at the left in meters per second. (A spike of a 90 m.p.s. fiber is shown in Figure 8.) All records have the same time scale. (Gasser and Grundfest, 1939.)

Alpha spikes recorded from single axons in spinal roots last 0.4 to 0.43 msec. (Fig. 8). In nerve fibers they may appear at this duration or a few hundredths of a millisecond longer. But the last few hundredths of a millisecond cannot be considered as being significant, as the recorded duration depends in part upon the material from which the spike is led—that is, upon the distance beyond the active point at which the potential is picked up. Now let us inquire into the range of the spikes to which this duration applies. Does it extend to the delta elevation, for example? The quickest way to become oriented as to the answer is to make an extrapolation of the duration of the elevation, as recorded after conduction, back to zero distance, where there is no dispersion of the axon potentials. In this way one obtains information forthwith about the whole group of five hundred or more fibers. The result of the procedure is apparent in Figure 5. At zero distance the duration of the delta group is the same as that of the alpha-beta group, about 0.5 msec. One could not let the matter rest, however, without recording the spike duration in single axons. When thus recorded the durations all fall between 0.4 and 0.5 msec., without systematic difference with respect to velocity (Fig. 6). Therefore, within the limits of the accuracy of measurement, in fibers in which the velocities range between 10 and 115 m.p.s., the spike durations may be considered as being constant.

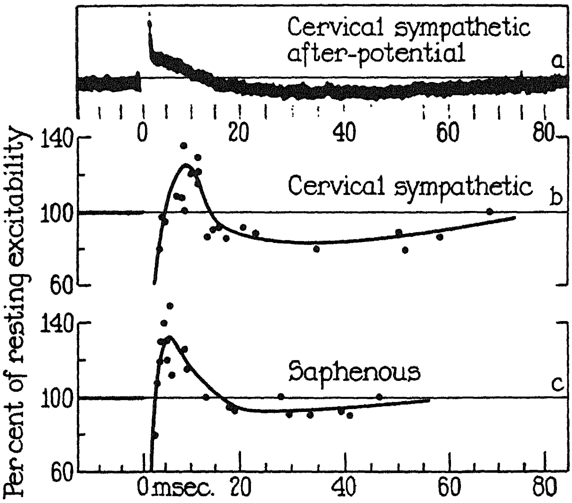
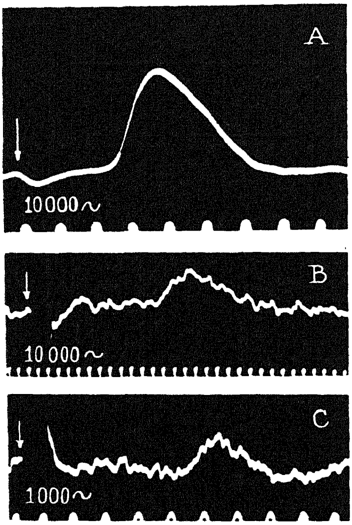


Figure 7. The after-potentials and excitability cycle of delta fibers. **a** and **b**, after-potential record and excitability cycle curve for the same nerve. **c**, excitability cycle curve for the delta fibers of the saphenous nerve of the cat. (Gasser and Grundfest, 1939.)

The refractory periods, on the other hand, vary in a continuous manner, as described by Blair and Erlanger for frog fibers. This observation was the occasion for considerable surprise, as no previous examples had been found of exceptions to Adrian's original finding that the absolutely refractory phase ends at the base of the spike. The variation of the refractory period is one of the legs of support of the contention that fibers vary to make a continuous series; therefore it demands special consideration. It is at this point that the usefulness of the after-potentials with their accompanying excitability cycles enters. For the refractory period has no greater significance in the characterization of fibers than have the after-potentials. And it may be said at once that the excitability cycles—and the after-potentials, where they can be recorded—are identical throughout the series. Figure 7 shows the after-potentials and the excitability cycle in the delta fibers of the cervical sympathetic nerve of the cat, and the excitability cycle in the delta fibers in the saphenous nerve. They resemble their counterparts in alpha fibers. Some hitherto unsuspected variable must enter into the determination of the refractory period, probably the fiber size, as it also enters into the determination of the resting threshold of excitation. Support for this view is also found in Hursh's measurements on immature alpha fibers. In young animals, in which the alpha fibers are small, the refractory period is longer than it is in the adult. Taking into consideration all the evidence, the medullated fibers of mammalian somatic nerves may be regarded as constituting a homogeneous series.



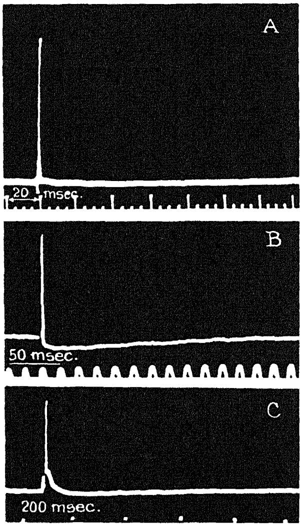


Figure 8 (left). Spikes recorded from unit axons of the A, B, and C groups. (See references 10 and 11.)

Figure 9 (right). After-potentials of the A, B, and C groups. The records are from multiple fiber preparations. (See references 10 and 11.)

In B fibers the spike, lasting about 1.2 msec., is longer than in A fibers (Fig. 8); and the after-potentials are in even greater contrast. Whereas the A fibers have a negative after-potential lasting about 15 msec., there is normally no visible negative after-potential in B fibers (Fig. 9), although one may be developed by special procedures. And whereas the positive after-potential in A fibers lasts only until about 70 msec. and in size amounts to only the equivalent of 0.1 to 0.4 per cent of the spike potential value, the B positive after-potential lasts 100 to 300 msec. and at its maximum has a size 1.5 to 4.0 per cent of that of the spike. The velocities found in B fibers range between 15 and 3 m.p.s. Thus, inasmuch as the slowest A fibers in the cat conduct impulses at about 10 m.p.s., there is an overlapping of velocities between the two groups. Likewise there is an overlapping in the thresholds of excitation. The break between the two groups comes in the durations of the spikes and the characteristics of the after-potential; and it is obvious that neither of these features is tied to the velocity. In this connection it is interesting to recall that the delta fibers in the saphenous nerve of the rabbit, which are A in quality, have velocities in the range usually associated with B.

In the C fibers, which conduct impulses at velocities between 2 and 0.6 m.p.s., another sharp break in the properties occurs. The C spike lasts about 2 msec. (Fig. 8) and is followed by a negative after-potential lasting 50 to 80 msec. (Fig. 9). The latter in turn is succeeded by a positive after-potential traceable for 1 to 2 sec. Wherever the C fibers have been properly studied they have been found to be unmyelinated. And they are set off from other fibers in other ways, as for example in their high resistance to asphyxia.

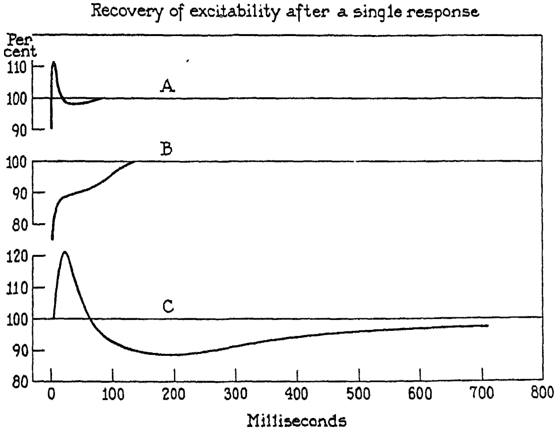


Figure 10. Course of recovery of excitability following single responses of A, B, and C fibers to excitation.

As a final point in the differentiation of fibers the course of their recovery of excitability following excitation must be mentioned. The excitability curves are quite characteristic and follow the configurations of the after-potentials (Fig. 10).

When all the data are tabulated it is apparent that while all velocities are present between the fastest and the slowest—between 115 and 0.6 m.p.s.—there is no corresponding variation in the properties. The fibers fall into three distinct groups with sharp boundaries. The classification of fibers made in this way, however, cannot be taken as the end of all classification. A number of observers have shown that there are large differences in the acetylcholine content of fibers—in the ventral roots as opposed to the dorsal roots, and in preganglionic fibers as opposed to postganglionic fibers. But these differences in metabolism do not reflect themselves in observations made with electrophysiological methods and they are part of another story.

With the confirmation of the validity of the division of fibers into groups, the way now became clear for the reinvestigation of the size-velocity relationship. Before entering upon a description of the final experimental drive made by Dr. Grundfest and myself, it will be necessary to mention two interim developments in order to fill in the picture of the background against which we were working. After observing a linear relationship between the spike size and conduction velocity in frog fibers, Blair and Erlanger reasoned that if the spike size is proportional to the axon area, as had always been held, the velocity must vary as the square of the diameter. Pumphrey and Young, on the other hand, concluded from observations made on velocities in relation to size in squid fibers that the velocity varies more nearly as the square root of the diameter. Even after due consideration is given to the difference between the two forms studied, the divergence of opinion inherent in these formulations is enormous. The correlating factor in one case is the fourth power of that in the other.

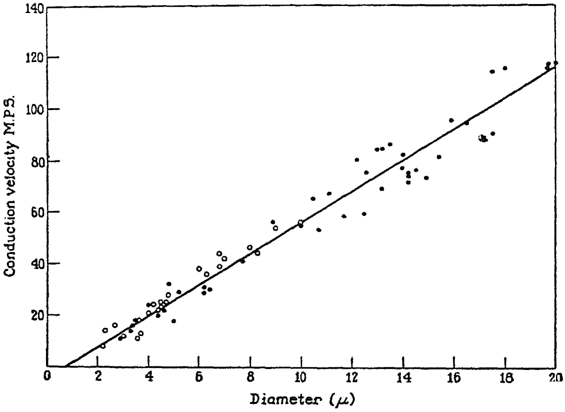


Figure 11. Velocities of conduction in the most rapidly conducting fibers of selected nerves, compared with the diameters of the largest fibers in those nerves. (Hursh, 1939.)

Before Pumphrey and Young's paper was published, Hursh in our laboratory was already making correlations between the maximal velocity and the size of the largest axon in mammalian nerves selected to yield collectively a wide range in diamaters. When the data were completed they represented velocities from 8 to 117 m.p.s., and the points connecting velocity to fiber diameter all fell about a straight line (Fig. 11). Not only did the data confirm the originally proposed diameter-velocity relationship, but they demonstrated its applicability at a range of velocities at which it had not previously been shown to apply. It may be asked, then, why the matter was not allowed to rest there and why we went on to the laborious reconstructions. The reason, as will soon become apparent, is that the reconstruction method affords a much more sensitive test of a velocity hypothesis.

Most of the observations were made on the saphenous nerve, usually of the cat, because of the well-marked elevations in the action potential with which the fibers may be fitted. After the action potential had been recorded and a map prepared of the distribution of the fibers according to sizes, it was possible from mere inspection of the map to make straightaway certain predictions about how the fibers would enter into the compound action potential. It can be seen in Figure 13 that the fibers fall into two main piles which should center on the alpha and the delta elevations. The delta elevation should start with fibers 3 to 4 μ in diameter; and, as the largest fiber in the nerve has a diameter of 14 μ and the factor relating the velocity of the fastest alpha fibers to that of the fastest delta fibers is approximately four, it follows that the delta elevation would be in the right place in the reconstruction.

After all the favorable preliminary indications it was surprising to see how poor were the first reconstructions made under the old rules. The delta elevation was about in the right place, but far too small. Numerous as were the small fibers, they did not supply nearly enough area to the end of the action potential. Another fault was that instead of a clean separation between alpha and delta, alpha crowded over and filled up the intervening space.

The most serious fault was the lack of potential area in the delta region—so serious that it revealed the fact that the assumption of the spike height varying as the cross-section of the axon must be incorrect. Almost every other part of the original rules had been questioned, rightly or wrongly. But it had occurred to no one to question this one, probably because it was hardly recognized that it was an assumption. It was based on the sound physical fact that the potential drop across a resistance, through which a current is flowing from a source that would yield the potential, E, on open circuit, depends upon the internal resistance of the source. As the resistance of the axons would vary as their cross-sections, this dimension was taken to be the controlling one in the calculation of the spike heights used for the first reconstructions; and, with the apparent success of the reconstruction of the early part of the action potential there was no reason for doubting its validity.

When once the difficulty was recognized, it was easy to see what the correct relationship must be. Blair and Erlanger, it will be recalled, had shown that the spike height in frog fibers varies directly with the velocity; and Zotterman had confirmed the relationship in mammalian fibers. Taken together with Hursh's demonstration that the velocity varies with the axon diameter, the correct interpretation of the observation of Blair and Erlanger is that the spike height varies as the diameter. Thus the sole support for the viewpoint that the velocity varies as the cross-section was removed. What had been neglected was the fact that the resistance of a nerve fiber depends not only upon its cross-section, but also upon a length. It has previously been pointed out that the spike durations are constant; therefore the wave length varies with the velocity, that is, with the axon diameter. Thus the proper statement about the internal resistance controlling the height of the spike is that the resistance varies directly as the diameter—because of the wave length—and inversely as the square of the diameter—

because of the effect of the cross-sectional area. The net variation, therefore, is inversely as the *first power of the diameter*. I will not bother you with the calculation of the spike heights when this variable is introduced. Suffice it to say that under the conditions obtaining in nerves, the spikes vary approximately as the axon diameters, as the experimental data indicate. It is the experimental fact, as illustrated in Figure 12, that I want to stress rather than the calculation.

With the needed potential area supplied, attention could be directed to other faults in the reconstructions. The alpha elevation was too broad and the alpha crest came too late. This fact meant too much temporal dispersion. Not only was all possibility that the velocity might vary as the square of the diameter removed, but linear variation itself appeared to be too great. And one thought of Pumphrey and Young's observations on squid fibers.

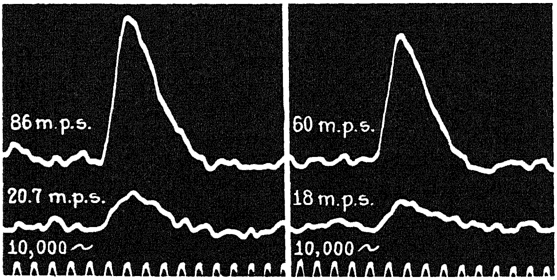
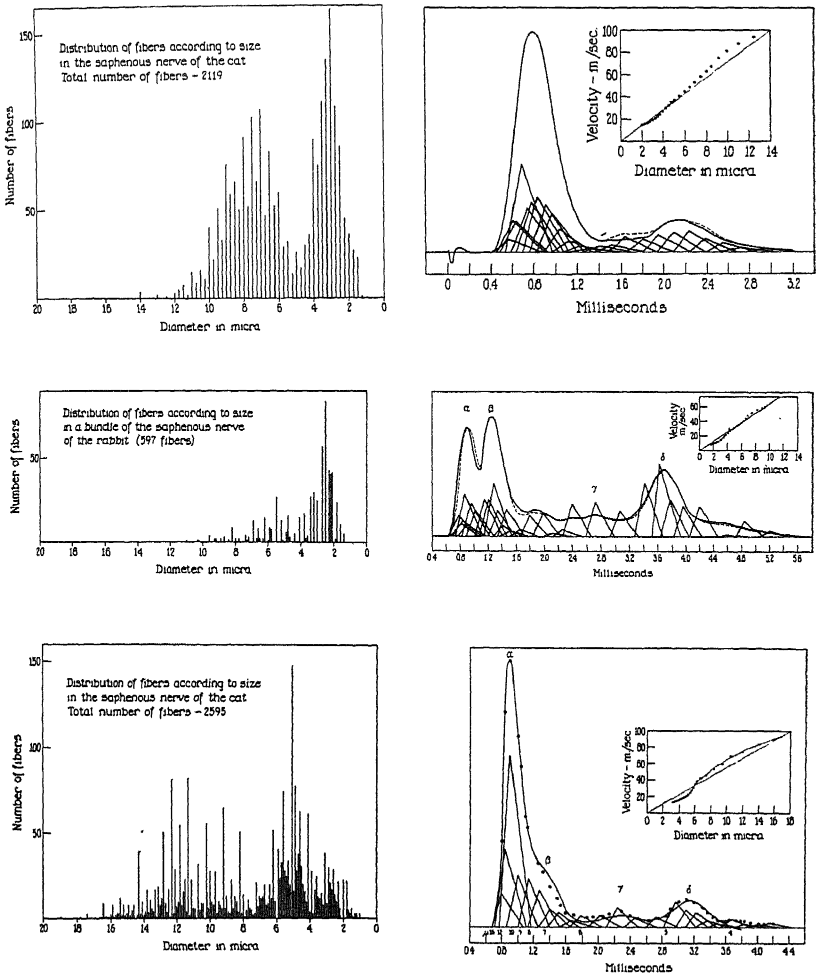


Figure 12. Comparison of the duration and heights of spikes in single axons conducting at different velocities in a branch of the saphenous nerve of the cat. The two groups are from different preparations. Left, $\text{velocity}_1/\text{velocity}_2 = 4.2$; $\text{height}_1/\text{height}_2 = 4.3$. Right, $\text{velocity}_1/\text{velocity}_2 = 3.3$; $\text{height}_1/\text{height}_2 = 3.8$. (Gasser and Grundfest, 1939.)

By now the correspondence between the recorded and the reconstructed potentials was so close that it was decided to change the plan of attack, in order to bring out wherein the discrepancies lay. It was decided to locate the fibers in the reconstruction in the right places, to cause them to make their proper contributions to the potential form, and then to calculate the velocities that would give them those positions. Thereby empirical velocity-diameter curves would be derived. In each instance excellent fits were obtained, as Figures 13 to 18 will show. The extreme sensitivity of the method will be noted. An error of a fraction of a micron in locating the slower fibers would throw their potentials grossly out of position. In each instance the same pattern emerges in the size-velocity curves. While their ends touch upon a straight line, the intermediate course is serpentine.

The next step was to account for the features of the size-velocity curves. The first question asked was whether any part of the curve was traceable to the fact that the outside diameters instead of the axon diameters had been used in the reconstructions. Use of the outside diameter is valid only in so far as its ratio to the axon diameter is



Figures 13–18. Distributions of fibers according to size and reconstructions of the action potentials from these distributions, shown for three different nerve preparations (Gasser and Grundfest, 1939). In the reconstruction curves the contour of the action potential as actually recorded is represented by a solid line. Where the reconstruction deviates from the record, the deviation is shown by lines made up of dashes or dots. Insets, corresponding size-velocity curves. Each dot in the curve represents a triangle in the reconstruction. Figs. 13 and 14 (upper). Saphenous nerve of the cat. Action potential record and reconstruction made for 4 cm. of conduction. Figs. 15 and 16 (center). Bundle ot the saphenous nerve of the rabbit. Action potential record and reconstruction made for 4 cm. of conduction. Figs. 17 and 18 (lower). Saphenous nerve of the cat. Action potential and reconstruction made for 6 cm. of conduction. In Figure 18 there may be seen the positions of the spike potentials in relation to the sizes of the fibers contributing them.

constant. A constant ratio was claimed by Donaldson and Hoke; but the more recent measurements of Schmitt and Bear and of Arnell are not in accord with their description. Arnell's data show that the myelin is relatively thicker on fixed mammalian fibers smaller than 8 micra. As the slopes of the velocity-diameter curves are greater below 8 μ, the observation appeared to be significant to our problem. If the fibers below that diameter have relatively thicker myelin sheaths, the fiber velocities determined by the axon would be slower than those indicated by the outside diameter and cause a depression in the outside diameter velocity curve.

We fortunately had in our possession a preparation of a fasciculus of the saphenous nerve containing 675 fibers, on which both the inside and the outside diameters had been measured. The ratios of the diameters were calculated. Above 8 μ the ratio was practically constant at 0.69, a value corresponding with Donaldson and Hoke's figure of 0.71. Below 8 μ the axon diameter outside diameter ratio fell off progressively.

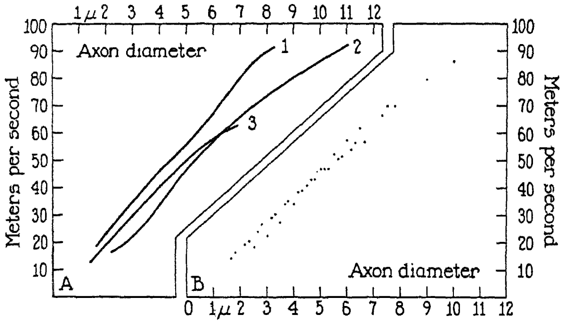


Figure 19. A, fiber diameter-velocity curves from Figures 14, 16, and 18 calculated in terms of the axon diameter and represented respectively in curves 1, 3, and 2. B, curves in A brought together by multipliers. (Gasser and Grundfest, 1939.)

With the aid of this curve, the size-velocity curves were recalculated in terms of the axon diameters, with the result that in two of the derivative curves the initial upward concavity disappeared, and in the third it was nearly obliterated (Fig. 19A). The three curves were then brought together by multipliers, in order to visualize the form of the axon-diameter velocity curve when freed from idiosyncrasies of the individual curves. While superficially the composite curve is linear, a close inspection reveals the fact that the points fall along a line having a slightly downward curvature (Fig. 19B). Whether or not this residual curvature is real cannot be stated. Some of the curvature can be accounted for on the basis of technical difficulties in measuring diameters, which I will not go into. And at times one gets perfect reconstructions of alpha spikes on the basis of a rigidly linear relationship between size and velocity. On the other hand, there is no theoretical reason why the graph should be a straight line, and in all probability it is a very flat curve approaching a straight line. Whatever deviation from linearity is present causes the velocity to change more slowly than it would in strict proportionality to the diameter of the axons. But in any case, the deviation is negligible compared with that in the root functions proposed by Pumphrey and Young for squid fibers.

As the facts now stand, the velocity of conduction may be considered to be approximately in linear relationship to the diameter of nerve axons. The correlation is an empirical one and would apply equally well to any property of the nerve fibers which varies in the same manner as the axon diameter. With this statement we have the last entry in the log of the course taken in the solution of what at the outset appeared to be a simple problem.

REFERENCES

1. **Adrian, E. D.** J. Physiol., **55,** 193. 1921.
2. **Arnell, N.** Acta Psychiat. et Neurol., **11,** 5. 1936.
3. **Bishop, G. H.,** and **Heinbecker, P.** Am. J. Physiol., **94,** 170. 1930.
4. **Blair, E. A.,** and **Erlanger, J.** Am. J. Physiol., **106,** 524. 1933.
5. **Donaldson, H. H.,** and **Hoke, G. W.** J. Comp. Neurol. and Psychol., **15,** 1. 1905.
6. **Erlanger, J.,** and **Gasser, H. S.** Am. J. Physiol., **92,** 43. 1930.
7. **Gasser, H. S.,** and **Erlanger, J.** Am. J. Physiol., **80,** 522. 1927.
8. **Gasser, H. S.,** and **Grundfest, H.** Am. J. Physiol., **127,** 393. 1939.
9. **Göthlin, G. F.** Thèse, Uppsala. 1907.
10. **Grundfest, H.** Am. J. Physiol., **127,** 252. 1939.
11. **Grundfest, H.,** and **Gasser, H. S.** Am. J. Physiol., **123,** 307. 1938.
12. **Hursh, J. B.** Am. J. Physiol., **127,** 131. 1939.
13. **Hursh, J. B.** Am. J. Physiol., **127,** 140. 1939.
14. **Lapicque, L., Gasser, H. S.,** and **Desoille, A.** Compt. Rend. Soc. Biol., **92,** 9. 1925.
15. **Lapicque, L., and Legendre, R.** Compt. Rend. Acad. Sci., **157,** 1163. 1913.
16. **Lapicque, L.,** and **Pézard, A.** Ann. de Physiol. et d. Physicochem. Biol., **14,** 582. 1938.
17. **Pumphrey, R. J.,** and **Young, J. Z.** J. Exp. Biol., **15,** 453. 1938.
18. **Schmitt, F. O.,** and **Bear, R. S.** J. Cell. and Comp. Physiol., **9,** 261. 1937.
19. **Zotterman, Y.** Skand. Arch. Physiol., **77,** 123. 1937.
20. **Zotterman, Y.** J. Physiol., **95,** 1. 1939.

Elements of Genetics

Many students who are interested in human heredity are bored by extensive discussions of plant and animal genetics. The new book, "Elements of Genetics," is particularly well adapted to such individuals. Especial attention is paid to human traits, and an exceptionally long list is discussed at some length. The author is careful not to be dogmatic in his classification of the modes of inheritance of the traits discussed, and yet at the same time to avoid cumbersome technicalities.

Interactions of heredity and environment are ably presented in an interesting manner. Attempts to induce mutations in animals by feeding lead, alcohol and various chemicals are discussed. Comparatively little space is devoted to chromosomal aberrations and none to biometric techniques. The final chapter is an up-to-date discussion of eugenics. A glossary of genetic terminology is included.

The book is attractively bound and printed upon a good grade of paper.

—*D. C. Rife.*

Elements of Genetics, by Edward C. Colin. 386 pp. Philadelphia, The Blakeston Company, 1941. $3.00.

THE INTERACTION OF NEURONES[1]

R. W. GERARD,
University of Chicago

That neurones interact is obvious from the simple consideration that each of you has several billion neurones in your cerebral cortex, yet remains a single personality. The general question I wish to raise is: How is this unification brought about? The existence of gross interaction is shown, more precisely, in many ways.

Lashley (1929) has offered impressive evidence of a mass function of the brain—not alternate to, but superimposed upon, its specialized local function—by studying the learning capacity of rats after the production of various brain lesions. The deterioration of learning ability he found to be highly correlated with the amount of cortex lost (r up to 0.86); but, since extensive criss-cross slicing of the whole cerebrum or removal of sufficient occipital lobe to destroy the same actual volume of cortex as destroyed by the cuts led to like learning losses; this did not correlate with the extent of interruption of recognized anatomical connections. What sort of neurone interaction might lead to this mass response?

Again, in the course of establishing a conditioned reflex, a particular afferent system comes to exercise control over an efferent oneup on which it normally has no action. In neurological terms, this means that two brain centers become able to interact physiologically as a consequence of having been repeatedly set into action together. How does the repeated ringing of a bell, when food is offered, open pathways between the auditory system and the salivatory nucleus?

Another form of interaction is manifested in the synchronized electrical beating of large numbers of neurones. This is widely manifest in neural masses—from the synchronized discharges of the uniformly illuminated retina (Adrian and Matthews, 1928), or the like impulse trains set up from the two respiratory centers and recorded in the phrenic nerves (Gasser and Newcomer, 1921), to the regular alpha rhythm of the human occipital cortex, and the equivalent regular beat of the isolated frog olfactory bulb (Libet and Gerard, 1939). How is this interaction achieved?

Closely related is the problem of the slowly spreading cortical waves seen in epilepsy or induced by convulsant drugs (Gibbs, Lennox and Gibbs, 1936; Adrian, 1936; Gerard and Libet, 1940). Even the well recognized dominance by more rostral neural masses, which check or suppress the activity of more caudal and phylogenetically older ones, presents a similar problem in interaction on a gross scale.

---

[1] The experimental work here reported was aided by a grant from the Dr. Wallace C. and Clara A. Abbott Memorial Fund of the University of Chicago.

Publication of this paper is aided by a grant from Mr. William Wallace Kincaid, Ellerslie-on-Niagara, Youngstown, New York.

At a finer level, a great mass of neurophysiological research has demonstrated in some detail the ability of one neurone to act upon another to change the state of the second (e. g. Symposium, 1939). This may be made to discharge and after-discharge or to cease action already in progress; its threshold may be lowered so that subsequent stimuli are facilitated, or raised so that they are suppressed; its potential may be shifted in the negative or in the positive direction; its metabolism may be increased or diminished. How are these effects brought about?

The mechanism of interaction, in this last case, is clearly that of synaptic transmission; and this of course analyzes further into chemical or electrical mechanisms. Some years ago (1932) I wrote, "Conduction along a nerve fiber involves excitation of a resting region by an active one, and both electrical and chemical components are present in the mechanism of propagation. At the ending, which is specialized, at least anatomically, either or both components might well be exaggerated to facilitate conduction over a critical region. Long enduring action or depolarization potentials or special chemical accumulation might equally well be utilized in various situations." To my mind, the enormous increase of information during the interim has not invalidated this position.

I do not propose to discuss the exciting controversy between those who insist on a material or humoral mechanism and those who equally insist on an energetic or electrical one. The chemical theories have faced a major difficulty, in accounting for very rapid changes, by emphasizing the appropriately high concentration of enzyme in junctional regions. The electrical ones have been similarly bothered by the problem of slow and enduring changes, and have interpreted these in terms of maintained interneurone bombardment and of long after-potentials. Since there is no anatomical basis for the former in autonomic ganglia, yet brief preganglionic tetany can alter the activity of ganglion cells for minutes afterwards (Bronk, Symposium), interneurone activity cannot be a universal explanation. On the other hand, it has long been known (Gerard, 1930), though often overlooked, that a few seconds tetanus may leave, even in nerve, considerable after-potentials which actually increase in magnitude during three or four minutes and endure for over fifteen.

Aside, however, from any chemical or electrical changes set up in highly localized fashion at a synapse, there is good evidence that each of these mechanisms acts more generally upon neurones, and independently of synaptic transmission. That the physico-chemical milieu of nerve cells can profoundly influence their activity or responsiveness, is now widely recognized. One need only recall, for example, the ability of an increased blood potassium concentration to arouse cats from anesthesia (Dubner and Gerard, 1939), or to triple the duration of the rebound limb positions following electrical stimulation of the deep cerebellar nuclei (Gerard and Magoun, 1936). I shall, therefore, in the remainder of this address, emphasize rather the electrical mechanisms which act grossly on the individual neurone and which are of prime importance in the interaction of the many.

Only in recent years has such non-synaptic electrical interaction begun to receive the attention it has long and obviously merited (e. g. Gerard, 1931). Now much evidence of its importance is appearing in the literature. Some examples are: the ability of a nerve action current to modify the excitability of a resting stretch of nerve even when the impulse with which the potential is associated is prevented by block from reaching this resting stretch (Hodgkin, 1937; Lorente de No, Symposium); the even more striking ability of the action currents from above such a block to re-initiate an impulse in the same nerve fiber two millimeters distant (Blair and Erlanger, 1939; Tasaki, 1939); the similar ability of the currents from one active nerve fiber to alter the thresholds of adjacent ones (Katz and Schmitt, 1940); and the tendency of separate axons in an isolated nerve (Adrian, 1930), of separated nitella cells lying in the same dish of water (Hill, 1939), and of individual spermatozoa clustered about a single egg, (Lillie, 1932), gradually to synchronize their rhythmic actions. I shall, however, base the further discussion on experiments carried out during recent years by Dr. Libet and myself on the isolated frog brain.

The frog brain is a peculiarly favorable preparation for study of the electrical activity of neurones. Its cells maintain the *in vivo* rhythm, some six beats a second of thirty microvolts' amplitude, for several hours after the complete isolation of the cerebrum. Indeed, the potentials are commonly larger and more regular *in vitro* than they were in the same brain in the unanesthetized frog, exposed earlier under ether. Even a tiny bit of brain, as little as 1/10 of a milligram carefully teased from the olfactory bulb, can maintain its regular rhythm. Obviously, no circulation changes can confuse the picture, and the supply of oxygen and other substances by diffusion is adequate. It is thus possible to vary, in controlled quantitative fashion such conditions as temperature, salt or drug concentrations, or the like, while keeping other variables unchanged. It could be shown, for example, that a rise in temperature increases not only the amplitude and the frequency ($Q_{10} = 2.3$) but also the regularity of the rhythm; while potassium increase, though accelerating the rhythm, soon disrupts it; and calcium, as usual, has the reverse action.

Further, the cells in the frog hemisphere are arranged in relatively simple patterns and form what amounts to a mosaic sheet near the ventricular surface. They are easily accessible to electrodes at either cell pole and thus, as we shall see, simulate the membrane of a nerve fiber studied by internal and external leads. Synaptic transmission in the isolated brain is retained under ordinary circumstances. Thus, brief tetanization of the olfactory nerve leads to an increase in amplitude of the olfactory bulb rhythm and to the appearance of waves at a higher frequency, and these changes may endure for several minutes.

Along similar lines, Mr. Tokaji and I have recently found that brief soaking of the brain in either acetylcholine or in eserine, at a concentration of 1 part in a hundred million, leads to a gradual increase (the maximum effect is not attained until a half-hour after the soaking) in the continuous activity and to the appearance of characteristic large diphasic repeated waves, Fig. 1. It is not yet certain, of course, that these drugs act here to enhance synaptic stimulation, but their low effective concentrations, and the ability of nicotine to abolish their action, strongly suggests this.

Finally, the neurone mass in this preparation shows striking synchronization. That the few hundred or thousand cells in a single olfactory bulb are beating together is made strongly probable from the mere existence of the ordinary rhythm; for, if each cell were active independently of the others, a large, smooth and regular potential wave could not result. The synchrony is made quite certain when this ordinary rhythm can be altered, by appropriate change in conditions, so that regularly repeated waves occur at frequencies between one and fifty a second, at amplitudes from a few microvolts to over two millivolts, and with shapes from almost pure sine waves to highly skewed, humped, and even polyphasic, spike-like profiles. Though such irregular waves could be the resultant of simple waves of individual cells, so timed in their appearance as to sum to the recorded wave shape, this is *a priori* unlikely and only possible at all on the basis of recurrent excitation circuits. Yet nicotine, which blocks such circuits, still leaves very regular skewed waves.

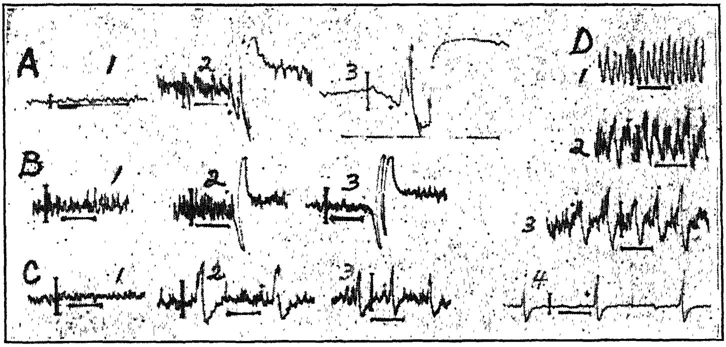


Fig. 1. Action of acetylcholine and eserine on isolated frog brain. Records in three horizontal groups (A, B, C) from three hemispheres, in vertical group (D) from olfactory bulb. Horizontal line = 1 second (read left to right), vertical line = 100 μV, except as indicated.

A 1. Normal (30μV); 2. 25 min. after 3 min. in 10^{-6}% eserine (HCl); 3. soon after 2, faster (300μV).

B 1. Normal; 2. 11 min. after 3 min. in 10^{-6}% acetylcholine; 3. 4 min. later (300μV).

C 1. Normal; 2. 24 min. after 3 min. in 10^{-6}% acetylcholine; 3. 9 min. later.

D 1. Normal; 2. 8 min. after 3 min. in 10^{-6}% acetylcholine (in serum); 3. 17 min. later; 4. 13 min. after 3 (300μV).

Cell synchronization is, therefore, present and can profitably be studied in the isolated brain. Thus, greater regularity should denote more perfect synchronization, and it should be, and is, more difficult to disrupt a more regular rhythm than a less regular one by desynchronizing agents, such as potassium. By such criteria it has been shown that synchrony is enhanced by an increase in temperature or calcium; by certain drugs, notably caffeine or nicotine; by a diminution of potassium or sodium; and, especially, by maintained constant currents.

The most useful property of this isolated brain, however, is its ability to generate slowly traveling waves; evoked especially conveniently by a brief soaking in caffeine. Following this treatment, there appear large surface-positive waves, of 0.1 to 0.2 second duration and one or two millivolts potential, each of which passes over into a surface-negative potential of lower amplitude and several times longer duration.

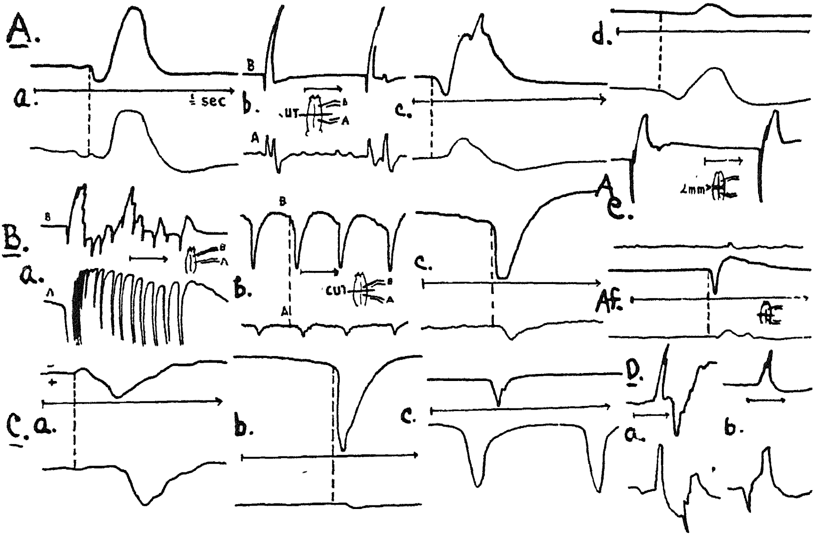


Fig. 2. Interaction across cut. Two channel simultaneous records.

A. a. Caffeine waves before cut; b. after complete transection across hemispheres, recording from each piece as shown; c. same later, showing front piece originating wave; d. still later, showing hind piece originating wave; e. pieces separated by 2 mm. (connected by Ringer's), note lack of interaction; f. pieces reapposed.

B. Another brain; a. caffeine waves before cut; b. after complete transection; c. same, faster speed, note that wave clearly spreads with finite velocity across cut.

C. Another brain; a. caffeine waves before cut; b. after complete transection between the two sets of electrodes; c. later, independent action of the two halves, showing non-interaction of recording systems.

D. Another brain; a. caffeine waves before cut; b. after cut.

The main wave, arising from a flat base line, is commonly followed by a train of satellite waves of progressively greater amplitude and lower frequency until the whole train stops. The entire sequence is repeated at regular intervals. Two channel recording shows that these caffeine waves travel over the hemisphere, most commonly in a rostro-caudad direction but sometimes in the reverse one, at the usual speed of 5 centimeters a second. (Fig. 2).

This slow propagation does not depend on synaptic excitation of successive cells, with or without interneurone circuits. The spreading caffeine waves are not altered by application of nicotine, which blocks synaptic responses, such as the on and off light response of the optic lobe, even in the presence of strong caffeine. Even more conclusive (since it might be argued that nicotine failed to block interneurone synapses which we could not directly test) is the finding that the caffeine waves can continue their longitudinal travel across a complete sharp cut made transversely through the brain at the middle of the hemisphere, providing the two brain halves are accurately reapposed. Separation of a fraction of a millimeter, even with Ringer solution in the gap, stops the wave at the cut; reapposition again allows it to travel from olfactory bulb to occipital pole, with no significant disturbance at the interposed cut. (Fig. 2).

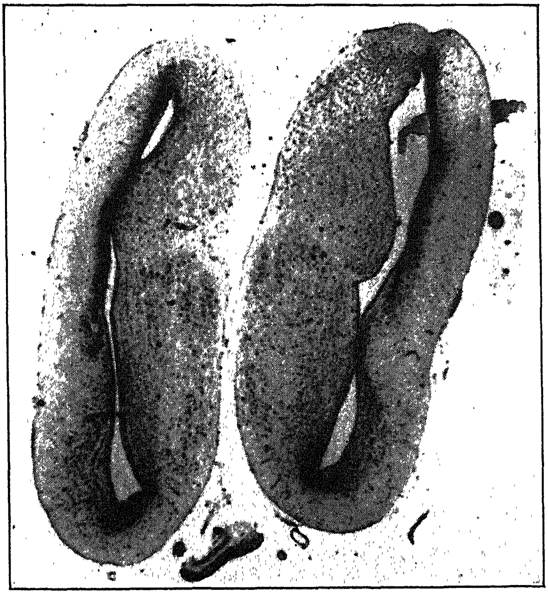


Fig. 3. Coronal section through frog hemispheres. Microphotograph ×15. Position of ventricular and pial electrodes indicated on right upper pallium.

Clearly, in this case, synaptic conduction is impossible; and a chemical mechanism cannot come in question. The probability was therefore strong that intercellular electric currents supply the mechanism for this wave propagation. If correct, it would follow that the activity of neurones in the normal brain, as well as in the caffeinized one, should be modified by passing appropriate constant currents through the brain mass—that is, by polarizing it—and, indeed, ascending or descending currents, of .05 milliamperes or less, do profoundly affect the electrical activity of the isolated hemisphere.

It will be useful at this time to present a theoretical interpretation in the light of which further data can be evaluated. The cerebral neurones, as can be seen in Fig. 3, form a sheet of closely packed cells near the ventricle and in a plane parallel to the pial and ventricular surfaces. Each cell is oriented with its dendrites towards the pia and its axon towards the ventricle. Let us assume that, in addition to the well recognized membrane potential, each cell is normally polarized along its perikaryon or soma, so that the dendritic pole is negative to the axonic. As seen in Fig. 4, the cell sheet would thus resemble a polarized membrane, as the nerve membrane, with an electric double layer. The postulated direction of the potential, as regards the outside and inside of the hemisphere is, of course, the reverse of that in the nerve membrane and, if correct, it should follow that an- and catelectrotonic effects produced by constant currents should also be inverted relative to the brain surface. We shall see later that this is the case.

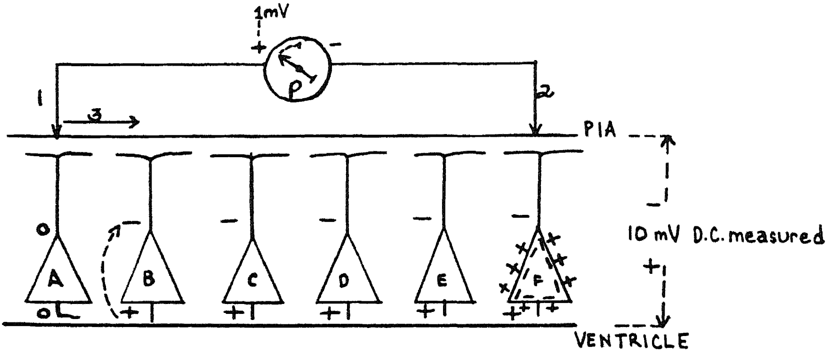


Fig. 4. Schema of cell layer in frog's cerebral hemisphere. See text. A caffeine wave is spreading as indicated by arrow 3 and has just discharged the somatic polarization of cell A. Cell B is discharging. The amplifier shows a pial surface positive wave of 1 mV. The usual interior-exterior polarization of the neurone surface is shown for cell F.

We postulate further that when the somatic potential is sufficiently decreased, that is when the axonic end of the cell moves in the direction of negativity relative to the dendritic, the cell becomes active and the somatic potential is discharged. Such a discharged cell, failing to oppose by its own potential the currents which tend to flow through and about it from the charges on neighboring cells, would act comparably to a depolarized region of the nerve membrane. The lowered resistance at this spot would permit adjacent somatic potentials to discharge, the neighboring cells would become active and depolarize, and a spreading wave of cell depolarization and activity would result. Similarly, one cell might actively send current through another with equivalent results. Since activation of one cell by another does not depend on synaptic transmission but on currents flowing through intercellular fluid, nicotine should not stop them, nor should a sharp cut providing the cut surfaces remain well apposed.

Many consequences of such a theory can be directly tested in terms of concrete predictions. For example, there should be a steady potential difference recorded between electrodes placed on the pial and ventricular surfaces of the thin hemisphere, the pial surface being negative to the ventricular. Measurements show a consistent DC potential, normally of 2–3 millivolts magnitude but with occasional much higher values, and usually in the right direction. The direction of this potential sometimes shifts spontaneously and can easily be altered by deliberate polarization across the thickness of the hemisphere. When traveling caffeine waves are then elicited, it is found, as the theory predicts, that the main wave has also reversed its polarity. In fact, as Fig. 5 shows, the direction and configuration of the caffeine wave correlates very well with the simultaneously measured P-V potential (pial-ventricular) as this slowly shifts in magnitude and direction.

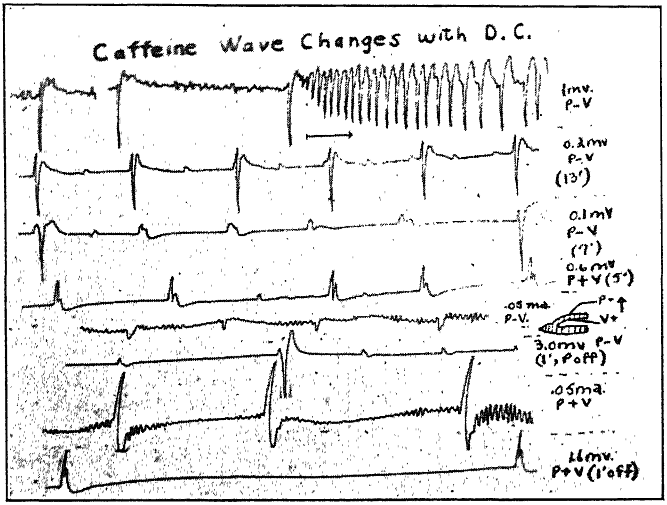


Fig. 5. Change in caffeine waves with P-V potential. From above down, time intervals between records are: 13 min., 7 min., 5 min. At 5th line, polarization is in progress as indicated, then 1 min. later. At 7th line reverse polarization in progress, then 1 min. later.

The theory also predicts that the caffeine waves, as measured between electrodes on the pial and ventricular surfaces of the hemisphere, should be larger than those recorded between two electrodes on the pial surface, and should always be simple in form even when the latter show polyphasic variations. These predictions have also been experimentally confirmed, the P-V recorded wave being regularly larger, sometimes showing two or more times the voltage of the surface recorded wave.

Polarization through the hemisphere's thickness, ventricle negative to pia, would tend to depolarize the somatic potential, and therefore should act comparably to cathodal polarization of a nerve. This it does, for it will regularly initiate waves in an otherwise inactive brain, and seems to cause the locus of origin of caffeine waves already present to shift towards or to the region of depolarization. "Anelectrotonus" has the inverse actions. Even the intensity and duration of the cell after-potentials are altered by polarization in a manner comparable to those of nerve.

It is thus obvious that this theory of somatic potential and intercellular electric currents, so closely analogous to the membrane theory of nerve conduction, serves well to explain the slowly spreading caffeine waves—as indeed it should, since it was devised for this purpose.

What is more important is its ability to explain other phenomena, as those of neurone interaction cited at the start of this address, without the necessity of introducing additional assumptions. Thus, for example, the spontaneous electrical beat recorded from brain neurones is probably a rhythmic variation of the somatic potential—indeed, if the membrane potential were to change simultaneously over the entire cell surface no external potential variation would appear—and the synchronization of the many beating cells follows simply from the above picture. Just as the current from a pacemaking nerve fiber or a nitella cell is able to sweep into unison with it other nearby units, about to fire off spontaneously in the course of their own rhythmic activity, so a pacemaking neurone (and not necessarily the same one at all times) would engage adjacent ones. Instead of having a slowly spreading wave, because the currents from one cell require a short time for their "detonator" action to stimulate the next, there would result an essentially simultaneous activity of adjacent units as their individual spontaneous rhythms fall into synchrony. The unifying action would spread rapidly to more peripheral units as the number of cells beating together increased and ever larger currents consequently flowed through the brain mass.

In the same way, by the interaction and summation of intercellular currents from large numbers of neurones, we can account for the phenomenon of a mass action independent of synaptic connections and for the existence of dynamic patterns of brain activity superimposed on, and partly independent of, the anatomical architecture. It is also obvious, I think, without developing the argument in detail, that the simultaneous activity of two nearby cortical regions, as in the course of conditioning, would alter the potential fields which would accompany the activity of either region alone and could so lead to the establishment of new functional patterns, of new conditioned reflexes. Finally, the somatic potential theory lends itself to a simple explanation of central inhibition which I shall shortly develop.

It will be desirable now to turn your attention again to the various interpretations of the functioning of the central nervous system which have been built up from the known properties of nerve fiber and synapse action, especially by Gasser and by Lorente de No. Gasser's theory of inhibition (Gasser, 1937), depending on the capture of an interneurone by one active neurone chain and so blocking transmission in a second chain to which it is also necessary, is familiar to you. I have diagrammed a slightly modified version of this in Fig. 6, which includes also a simple extension of the reasoning to account for the phenomenon of conditioning.

Of course, such nerve impulse theories fit admirably the phenomena of summation, facilitation, after-discharge, and the like—in connection with which they have been developed—and I daresay they could be extended to account for the phenomenon of synchronization, though this would certainly involve difficulties. But it is important to note that all such interpretations rest heavily on very precise structural relations between neurones, especially on the number and distribution of synaptic end-feet, and on the no less precise timing of the arrival of excitation from different sources so that they can or cannot sum their effects, as the case may be. And, despite the clear experimental demonstration of many of these necessary conditions, there remain certain serious difficulties to face.

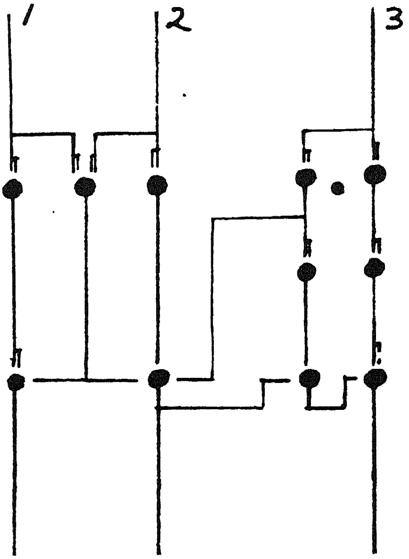


Fig. 6. Assume two synaptic endings on a neurone must act together to produce excitation. Then an impulse in afferent fiber 1 or 2 will excite its appropriate efferent. But 1 inhibits 2 by capturing the common interneurone. When 1 and 3 are active together, 1 can discharge the efferent neurons of 3.

The facts outlined earlier, for example, that block of synaptic excitation by nicotine or of nerve fiber conduction by anatomical section do not abolish neurone synchrony or the spread of slow waves, are not reconcilable with pure nerve-impulse theories. Similarly for the equal loss of learning capacity, with equal loss of cortical tissue, with rat cortex destruction, independently of whether or not nerve pathways have been extensively interrupted. A further problem is encountered in interpreting the effects of influent nerve impulses reaching different parts of a single neurose. It does not seem probable that groups of end-feet synapsing on widely separated dendritic branches can produce effects which interact, either for summation or inhibition, by any sort of membrane-propagated change along the neurone in question. Not only would a propagation of graded intensity, rather than of all-or-none character, be necessary, but also qualitatively different ones for excitation and for inhibition would be needed.

This latter difficulty would not arise if all the phenomena of inhibition could be accounted for by the shift of interneurones from one pathway to another. But such an interpretation does not seem able to account for all these phenomena. To take just one: ganglion cells, which are kept in a state of inhibition by maintained stimulation of inhibitory nerves to them, not merely fail to increase their resting rate of metabolism, but actually show a very considerable diminution in respiration (Dann and Gardiner, 1930). No type of theory which accounts for inhibition by any kind of increased activity, can be reconciled with these facts. Rather, each neurone itself, under the influence of whatever factors, must change its state in a direction inverse to that of excitation.

Finally, I must mention a body of data which throws some doubt on the interpretations of neurone function which require precise and set anatomical connections. Weiss (1940) has recently made separate implants under the dorsal fin of amblystoma of an extra leg and of a piece of spinal cord from another salamander. Ninety per cent of the neurones in the cord fragment disappear, and the remainder become completely disorganized by migration and growth of new processes. Dorsal column cells, for example, may sprout fibers which run out from the graft to form motor and sensory connections with tissues of the host and, particularly, with the neighboring limb implant. Yet, as the limb becomes innervated, it shows at first repeated generalized contractions, indicating synchronized discharges from many neurones, and later there appear well defined reflex responses which possess the usual attributes; of spacial and temporal summation, of gradation of response with stimulus intensity, of after-discharge, and the like. Inhibition has not been observed. The extent of synchronous action of these morphologically disturbed neurones is particularly well illustrated by implanting two legs on opposite sides of the cord section; for in such a preparation the two limbs always respond together.

In terms of the somatic potential, a theory of inhibition requires one essential assumption. If excitation follows the decrease or disappearance of this potential, inhibition should result when it is enhanced. Just as diminished polarization is associated with increased metabolism, increased polarization, produced from without, should lead to a decrease. We have in fact some evidence on nerve, although it is far from decisive, that a cathodally polarized region increases, an anodally polarized one decreases, its respiration. The further assumption needed is that those synaptic endings which excite a cell tend to be grouped at one pole, while those which inhibit it are grouped at the other. Then an identical action, such as the production of a local negativity, would, in the case of an excitatory synapse oppose and so diminish the somatic potential, in the case of an inhibitory synapse sum with and so increase it.

To what extent such an anatomical disposition of functionally different endings does exist in the central nervous system is unknown, but that it can exist is clearly shown by the case of the Mauthner cell in certain fish brains. This large single cell, with a soma well over a millimeter long and two dendrites extending through the thickness of the tegmentum, receives synaptic connections of several well recognized types and from a number of known pathways (Bodian, 1937). (Fig. 7). End-feet on the axone hillock are of the small button type, come from fibers in the posterior longitudinal bundle, and are supposed to produce inhibition. End-feet on the dendrites are of the club type, come from the acoustic system, and are believed to cause excitation.

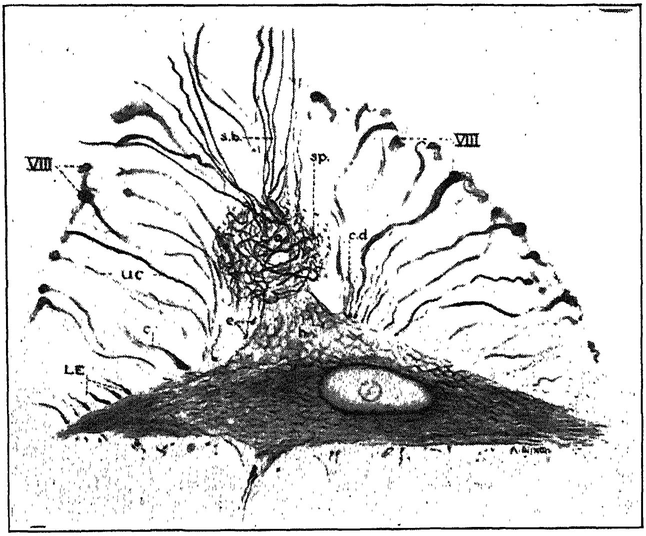


Fig. 7. Mauthner cell of the gold fish brain (from Bodian). Synaptic endings on the axone and axone hillock (above) are anatomically distinct from those ending on the soma or dendrites. This affords an anatomical basis for the type of inhibition here suggested.

The evidence, then, seems to show that nerve impulses traveling along definitive pathways are important in controlling the interaction of neurones, especially as they combine with one another in producing the special patterns of motor discharge and other fine regulations; and that many chemical substances, brought in the blood stream or formed locally, are likewise able to act upon neurones, regionally or generally, to modify their actions. But, in addition, there is the third factor, of electric currents flowing through and between neurones, which, perhaps more than either of the others, is involved in the interactions of nerve cells in larger groups and masses and which may also play an important role in certain of the more specific actions of one cell on another.

BIBLIOGRAPHY

Adrian, E. D. 1930. Proc. Roy. Soc. B., **106**: 596.
Adrian, E. D. 1936. J. Physiol., **88**: 127.
Adrian, A. D., and **R. Matthews.** 1928. J. Physiol., **65**: 273.
Blair, E. A., and **J. Erlanger.** 1939. Am. J. Physiol., **126**: 97.
Bodian, D. 1937. J. Comp. Neurol., **68**: 117.
Dann, M., and **E. M. Gardiner.** 1930. Proc. Soc. Exp. Biol. and Med., **28**: 200.
Dubner, H., and **R. W. Gerard.** 1939. J. Neurophysiol., **2**: 142.
Gasser, H. S. 1937. Harvey Lectures, **32**: 169.
Gasser, H. S., and **H. S. Newcomer.** 1921. Am. J. Physiol., **57**: 1.
Gerard, R. W. 1930. Am. J. Physiol., **93**: 337.
Gerard, R. W. 1931. Quart. Rev. Biol., **6**: 59.
Gerard, R. W. 1932. Physiol. Rev., **12**: 546.
Gerard, R. W., and **B. Libet.** 1940. Am. J. Psychiat., **96**: 1125.
Gerard, R. W., and **H. W. Magoun.** 1936. Proc. Soc. Exp. Biol. and Med., **34**: 755.
Gibbs, F. A., W. G. Lennox, and **E. R. Gibbs.** 1936. Arch. Neurol. and Psychiat., **36**: 1225.
Hill, S. E. 1939. Am. J. Physiol., **126**: 534P.
Hodgokin, A. L. 1937. J. Physiol., **90**: 211.
Katz, B., and **O. H. Schmitt.** 1940. J. Physiol., **97**: 471.
Lashley, K. 1929. Brain Mechanisms and Intelligence, Univ. of Chic. Press, Chicago.
Libet, B., and **R. W. Gerard.** 1939. J. Neurophysiol., **2**: 153.
Lillie, R. S. 1932. Protoplasmic Action and Nervous Action. Univ. of Chic. Press, Chicago.
Symposium. 1939. J. Neurophysiol., **2**: 361.
Tasaki, I. 1939. Am. J. Physiol., **127**: 211.
Weiss, P. A. 1940. Proc. Soc. Exp. Biol. and Med, 44; 350.

Microbiology

Laboratory manuals in bacteriology differ principally in respect to the number of exercises, the order in which they are arranged, the introductory remarks to the exercises, and the clarity of directions. This manual is fairly complete, containing twenty-four studies, sufficient for a course in general bacteriology. The arrangement of the exercises may be questioned. In Exercise 4 the nitron cycle is diagrammed but nitrogen fixation is relegated to Exercise 19. Why the nitrogen cycle should be considered before and not as a part of bacterial physiology is difficult to see. Exercise 9 is on Typhoid and Dysentery in Water: Sewage is considered in Exercise 20. Exercise 12 in on Tuberculosis: Exercise 21 on Diseases of Human Beings. The introductory remarks are not without errors. Few will agree with the statement in the Exercise on Dental Bacteriology that *Streptococcus hemolyticus* is probably the most common organism in the mouth and that "carious and putrescent teeth may be a real predisposing cause of tuberculosis, as decayed teeth afford lodgment and a portal of entry for such microbes by way of the root canal." The exercises are well illustrated and the directions clear. At the end of each exercise is a list of pertinent questions and a list of references. The Appendix contains a glossary and directions for the preparation of stains and media. However, even though the errors in fact were overlooked, the arrangement of the exercises is such that it would be difficult to fit this manual into many courses in general bacteriology.

—*J. M. Birkeland.*

Microbiology Laboratory Manual, by Paul W. Allen and George M. Cameron. 243 pp. St. Louis, Mo., The C. V. Mosby Company, 1940.

ENCEPHALIZATION OF MOTOR FUNCTIONS DURING THE EVOLUTION OF THE PRIMATE NERVOUS SYSTEM

J. F. FULTON, M.D.,
Laboratory of Physiology, Yale University School of Medicine,
New Haven

I. INTRODUCTION

I had the privilege of spending part of August and most of last September in the gracious and hospitable atmosphere of Scandinavia, and since the visit was more prolonged than I had anticipated I put my time to good use by studying and collecting the works of that great Swede, Carl von Linné.

You are no doubt aware that he introduced the term "Primate," and since I was eager to learn how his concept of the first order of mammals had developed during the course of his scientific life, I traced the order through the various editions of his *Systema naturae*. The order is recognized in the first edition of the *Systema*—published in 1735 when Linné was 27 years of age—but under the name "Anthropomorpha," although the structural characteristics are not clearly defined. He merely described "dentes primores 4. utrinqu: vel nulli." Pectoral mammae and several other specific structural details are mentioned in the second (1740) and sixth (1748) editions,[1] but "Anthropomorpha" is retained as the name of the order, and it is not till the celebrated tenth edition of *Systema naturae* (1758–59) that the word "Primates" makes its appearance. Linné placed emphasis upon teeth as a basis of classification and definition of a primate from the 10th edition runs somewhat as follows:

"A quadruped with four parallel incisors, single canines, two pectoral mammae, hands rather than paws, two complete clavicles and an arboreal habitat."

Linné included the bat in his original classification and his definition of the order would also have embraced many related forms, such as the flying lemurs, tree shrews, etc. The *Bradypus*, for example, were included in the first, second and sixth editions, but they were dropped from the Primates in the tenth edition and in the twelfth.[2] To the Linnean characteristics, one nowadays, in defining the primate, adds that it has five fingers and five toes, usually flat nails, the first and second digits being opposable; the thumb and hallux may be atrophic. Usually a single offspring is produced at birth in a completely helpless condition, but twinning occurs normally in some of the lower primates, and multiple birth may rarely occur in all forms.

---

[1] The only editions of *Systema naturae* prior to the tenth that Linné himself revised.

[2] The twelfth edition was in part revised by Linné, and was the last edition that he touched.

I cannot here go into Linné's subdivisions of the primates, but let me briefly remind you that one now recognizes three suborders of primate, the *Tarsioidea, Lemuroidea* and the *Pithecoidea.* Their characteristics are as follows:

Tarsioidea. The group of animals nearest the stem of the primate tree are believed to be the tarsioids which are represented by only one existing species, *Tarsius Storr.* Recent studies of Matthew (1928), Chester Stock (1938) and others, indicate that tarsioids similar to existing species were found in the middle Eocene, and that they flourished then in this hemisphere and in Europe, as well as in the Orient. At present they occur only in a limited part of Melanesia, namely the southern Philippines, the Celebes, Northern Borneo, the Malay peninsula, and possibly in some intermediate islands. Few, if any mammals, other than *Tarsius*, have survived from the middle Eocene and hence they must be regarded as among the oldest existing mammals—they are indeed "living fossils."

Interest in the comparative study of cerebral function prompted me two years ago to make a trip to the southern Philippines to study the *Tarsius* with a view to exploring the feasibility of transporting them to this country by air (Fulton, 1939). Tarsiers had not hitherto been brought either to America or to Europe, although the attempt had been made on several previous occasions. Too little was known of their feeding habits, and of their uncertain temperament. While in the Philippines I made the acquaintance of a retired army captain, Mr. Norman Cook, who, while stationed in the Davao Gulf in southern Mindanao, had succeeded in keeping tarsiers as pets and he passed on to me his notes concerning their feeding habits and other features of their natural history (see Cook, 1939; see also Lewis, 1939).

Among other things Captain Cook's notes indicated that tarsiers would eat only living food, and, as had long been suspected, he found that they were primarily insect-eating. Profiting by this information, I succeeded in keeping a number of specimens alive and transported one by Clipper back to Honolulu, but in the old clippers odds were against one because livestock had to be carried in unheated baggage compartments which at 12,000 feet frequently fell to a subfreezing temperature. I made arrangements, however, with an enthusiastic young naturalist named John Eckman to bring back some specimens by boat and these arrived in November, 1938. A pair, male and female, have survived for eighteen months in my laboratory (Catchpole and Fulton, 1939).[3] These are, I believe, the first tarsiers to be maintained in captivity outside of Melanesia. The male is just becoming sexually mature; the female's sex cycles have been closely studied, but she did not reproduce. It is of some interest that this specimen of *Tarsius* has proved to have quite regular 26 day cycles (oestrus).

The morphological characteristics of the tarsioids indicate that they occupy a place of transition between the insectivores and the primates. Hence, a study of their brain from the structural as well as from the functional standpoint is of the greatest possible interest (see Woollard, 1925, 1935; also Woodward *et al.*, 1919).

---

[3] Both animals died quite suddenly of filarial infestation in June and July, 1940. some twenty months after reaching this country.

Lemuroidea. An offshoot of the primate stem is found in the lemurs, galagos, pottos, aye-ayes of Central Africa and Madagascar which answer to Linné's definition of a primate. They are less significant from the point of view of the primate evolution than are the tarsioids, because they probably represent an offshoot considerably distant from the base of the primate tree. However, they are more available than are the tarsioids and exist in a great many species.

Pithecoidea. An enormous branch of the order of primates is grouped under the pithecoids which include two large divisions (i) the Old World Monkeys (catarrhines) including all the apes and man and (ii) the New World Monkeys (platyrrhines). Hence, from the point of view of comparative study of the brain, the suborder Pithecoidea includes those forms to which attention is ordinarily directed. The grouping within the three suborders is indicated in the following table:

ORDER I: PRIMATES

I. TARSIOIDEA, a rare insect-eating primate which has changed little since Eocene times and exists in only one Genus: *Tarsius* Storr (several species or varieties). They are nearer the base of the primate stem than any other extant form.

II. LEMUROIDEA, a lowly offshoot of the primate stem, with tarsioid affinities, exist in four families:

1.	*Lemuridea*	Lemurs.
2.	*Lorisidea*	Loris, Potto.
3.	*Galagidea*	Galago ("Bush-baby").
4.	*Daubentonudea*	"Aye-aye."

III. PITHECOIDEA, an enormous group including Old World (*Catarrhini*) and New World (*Platyrrhini*) monkeys, the anthropoid apes and man, divided in six families:

MONKEYS

(*Platyrrhini*)

1.	*Hapalidae*	Marmoset.
2.	*Cebidae*	Ring-tail, Spider, Woolly, Howler.

(*Catarrhini*)

3.	*Cercopithecidae*	Langur, Four-fingered, Green and Red Military Monkey, Macaque, Japanese Ape, Baboon, Mandrill.

ANTHROPOID APES AND MAN

(*Catarrhini*)

4.	*Hylobatidae*	Gibbon.
5.	*Pongidae*	Orang-utan, Chimpanzee, Gorilla.
6.	*Hominidae*	Man (only one existing species).

II. THE COMPARATIVE APPROACH

Marshall Hall (1833) insisted that the nervous system is to be regarded as a group of segmental reflex arcs which had become functionally interrelated in the course of evolutionary development, the headward segments having become dominant over the segments more caudally situated. The most conspicuous feature in the evolution of the brain, especially of primates, lies in the growing dominance of the cerebral cortex over all lower levels of nervous function.

Evidence of this dominance has been inferred from the increased complexity of the anatomical matrix in man and chimpanzee, as compared with pithecoid monkeys and lemuroids; but complexity of the matrix has of itself little meaning in the absence of functional analysis. From the response to *stimulation* important indications have been obtained concerning functional complexity. The exposed brain of various animals had been stimulated in 1800 by Aldini (1804), during the controversy which followed the discovery of animal electricity (1791), but the motor area as such was not disclosed. The German neurologist, Hitzig (1874), was the earliest to stimulate the motor area of the monkey and to compare his results with those obtained in the dog, but he did not compare the monkey with other primate forms. An abortive attempt in this direction was made by Beevor and Horsley in 1890, but the first systematic comparison of monkey, orang, chimpanzee and gorilla, was made by Sherrington and his collaborators between 1892 and 1917 (see especially Leyton and Sherrington, 1917). Cushing (1909) and Foerster (1936) later extended corresponding studies on responsiveness to electrical stimulation to the human brain (see also Penfield and Boldrey, 1937).

Another functional approach, more revealing than that of electrical stimulation, lies in comparative study of the effects of ablation of corresponding areas of the brain in different primate forms. It was David Ferrier (1875) who first proved in the monkey that if a region excitable for the arm is removed the arm becomes paralyzed. Leyton and Sherrington (1917) made a similar observation in the chimpanzee, and they imply that paralysis was more profound relatively in the chimpanzee than in the monkey when a homologous area was removed; no emphasis, however, was placed upon the more enduring character of the paralysis in anthropoid as compared with monkey.

In recent studies begun late in 1930 with Allen D. Keller (Fulton and Keller, 1932) and since continued over a period of ten years with a series of collaborators, we have had opportunity to make a systematic comparative study of the effects both of stimulating and of ablation of some forty different species of primates, beginning with pottos, galagos and marmosets, and extending through old and new world pithecoid monkeys, four orangs and some 80 chimpanzees. More than two thousand pithecoid monkeys have been used in the course of the study.

Evidence of Encephalization

The most primitive nervous system, even that of the earthworm, is organized in terms of functional levels, and it is obvious that the more headward levels are dominant over the more caudal segments. The extent of this dominance, however, varies widely in different species, and it is for this reason that much importance is attached to the comparative physiology of the central nervous system. Such comparative studies have progressed in two important directions: (i) analysis of the gradual encephalization of function, and (ii) investigation in a given form of functional localization in the cerebral hemisphere. The last phase of the problem will be touched upon at the end of this discourse.

Motor systems. An illustration of differing degrees of dominance of the headward segments is found by comparison of cat with monkey. The cat (or dog) after removal of its cerebral hemispheres exhibits essentially normal locomotor movements; it is able to walk and to maintain itself upright against the force of gravity. An adult pithecoid monkey, however, when it loses its cerebral hemispheres, never regains its ability to walk; in other words, the control of locomotor movement has, in these primate forms, become almost completely taken over by the cerebral cortex. Locomotor function has become, as we asy, "encephalized."

There are certain relatively constant features of organization of the brain in all primate forms. The first is the position of the motor and sensory areas. In pithecoids the cerebral hemisphere is divided by a fissure, usually referred to as the "central sulcus," which separates the rostral (motor) from the caudal (sensory) portion of the hemisphere. In some of the Lemuroids there is a small dorsal sulcus that sometimes unites with sulcus rectus to form a primitive central sulcus (Connolly, 1936, p. 307). In *Tarsius* the hemisphere is usually quite smooth, but occasionally in *Tarsius*, as in the marmosets, there is a slight indentation coinciding with the posterior margin of the motor area (Woollard, 1925). The posterior division of the cerebral hemisphere, *i. e.*, the part lying caudal to the central sulcus, is primarily sensory in function and receives the great sensory projections from the thalamus and from lower spinal levels. The frontal lobes constitute the anterior portion of the hemispheres and include all tissue lying rostral to the central sulcus. This part of the hemisphere is primarily motor in function, but it also has a vast assemblage of interneurons which increase enormously in extent as one ascends the primate scale. The fore part of the frontal lobe is made up almost entirely of interneurons, and the region itself is referred to as the "frontal association areas." They are primarily concerned with higher intellectual functions, *i. e.*, memory and the capacity to plan for future action.

How does one know that the brains of chimpanzee and man are more encephalized than those of pithecoid monkeys, lemuroids and tarsiers? A suggestion comes from stimulation of the frontal lobes. The motor area of a tarsier has never been stimulated—the animal is still too rare and too precious—but I have stimulated pottos and galagos, which belong to the lemuroids, and also marmosets, and there are, in addition, several reports of stimulation of prosimiae in the literature (Volsch, 1906; Mott and Halliburton, 1908). It is strikingly true that only the most stereotyped movement patterns can be evoked from the central cortex of these primitive primates, whereas in chimpanzee and man highly discrete movements of individual fingers, corner of the mouth, the eyelids, the vocal cords and other individualized movement patterns can be evoked on cortical stimulation. Moreover, in man and chimpanzee there is a mosaic of sharply circumscribed foci controlling these specialized movements; while in the lemuroids the distribution of excitable points is homologous, but excitable foci are much less individualized.

The evidence of encephalization becomes much more impressive, however, from study of the effects of isolated ablation of those areas in the frontal lobe which an excitation gave movement, *e. g.*, of the leg. If the leg area is removed, the leg itself becomes paralyzed. *The extent and duration of the paralysis, however, varies widely in different forms.* It was mentioned that a cat, after complete removal of the hemispheres, is able, after a period of several hours, to walk about as if nothing serious had happened. The galago, potto and marmoset behave much as would a cat, although they exhibit a somewhat more enduring paresis. Mott and Halliburton (1908) were also struck by the slight character of the paresis following motor area ablation in the lemur. On removal of the leg area of a galago or potto, the leg shows obvious weakness for a few days, but power is regained after a period of time and the animal ultimately progresses as if nothing had happened. Pithecoid monkeys, such as the macaque, exhibit a profound paralysis when the foot area is removed, but recovery gradually occurs and after a few months the animal may move its foot almost normally in ordinary locomotor movements (see Fulton and Keller, 1932); signs of weakness, however, persist indefinitely in circumstances of fatigue, for even six months or a year after destruction of the leg area an animal will begin to drag its affected foot after a fatiguing chase. Hence, the mechanism governing foot movements are sufficiently encephalized in the macaque monkey to give some degree of *permanent* deficit when the foot area is removed. The baboon is considerably more affected than a monkey, and the gibbon lies clearly between the baboon and chimpanzee in intensity of its cortical paresis. Turning to chimpanzee and man, a far more profound paralysis results than in pithecoids or in the gibbon, when the foot area is ablated, *i. e.*, both chimpanzee and man exhibit a permanent and readily recognized motor deficit when the foot area of the frontal lobe is destroyed.[4]

If one compares the hand instead of the foot, the difference between species is even more striking, for a human being whose arm area has been destroyed, can never again use his fingers for the fine movements essential to play the piano, or even to button a shirt. Monkeys, on the other hand, although they do not ordinarily play the piano, exhibit other exquisitely delicate movements of the fingers and these show far less ultimate impairment following a lesion of the arm area than those of chimpanzee and man. Hence, we are led to conclude that the patterns of skilled movements are more highly encephalized in man and ape than in monkey.

In passing, it is interesting to note that control of movements of the tail in certain prehensiled tailed South American monkeys is so completely encephalized that when the tail areas are removed bilaterally, the tail itself becomes permanently and completely paralyzed, exhibiting only a spastic prehensility similar to the condition of spasticity encountered among primates after decerebration (Fulton and Dusser de Barenne, 1933). Human tails occur atavistically and some have been motile, implying cortical representation (Ross Harrison, 1901).

---

[4] These comparisons, especially among the prosimia, are based upon unpublished observations. For the pithecoid monkey, baboon, gibbon and chimpanzee, see Fulton and Keller, 1932.

Sensory systems. One may cite many parallels in the sensory sphere of similar encephalization of function. One of the most striking is that of the visual system. In fish, the optic system appears to be without significant connection with the forebrain and removal of the cerebral hemisphere causes no obvious impairment of vision, although behavioural disturbances are said to follow (G. K. Noble, unpublished). According to Schrader (1889), much the same is true of reptiles and birds. However, in rodents, particularly rabbit and rat, the visual cortex becomes encephalized; if the occipital lobes are removed, pattern vision is impaired, but the capacity to discriminate between differing intensities of light still remains unaffected (Lashley, 1932). Marquis (1932, 1938) has shown that dogs appear for a time completely blind after removal of the occipital lobes, but that brightness discrimination eventually returns with little or no impairment, while object vision is entirely destroyed. In monkeys object vision and brightness discrimination disappear entirely; a considerable degree of brightness returns (Malmo, unpublished). Man is rendered completely and permanently blind by extensive injury of occipital lobes, and he regains no consciousness whatsoever of light when this part of this cerebral hemisphere has been destroyed.

The encephalization of other categories of sensory functions follow a parallel schema, notably in somatic sensation in relation to the parietal lobes (see Ruch, 1935, and Ruch, Fulton and German, 1938).

When one approaches a given function of the human brain from the comparative standpoint by studying the particular function in a series of animals extending from tarsier and the lemurs up through the monkeys and the great apes, one can "extrapolate" quite accurately and predict how man will defer in regard to this particular function.

So much then for the principle of encephalization. Clinical neurologists often remark: "Well, you are working on cats and monkeys and your results are, of course, not applicable to the human being." My reply to this is generally somewhat direct, namely, that, if one approaches human function from a comparative standpoint far more basic light can be thrown upon it than by concentrated studies carried out on man himself without reference to his forebears in the evolutionary scale. A study of the monkey is also quite meaningless so far as the rest of the animal kingdom is concerned, unless a given function in one species is compared with the corresponding studies on forms occupying differing positions in the animal scale. The comparative approach to the human brain explains why it functions as it does.

III. FUNCTIONAL LOCALIZATION IN THE FRONTAL LOBES

The greater part of the cerebral cortex is made up of six primary layers of cells, but each layer has a different *cellular architecture.* The frontal lobes are subdivided on the basis of cytoarchitecture into a number of structurally discrete fields to which Korbinian Brodmann (1909), the Armenian histologist, gave an erratic series of numerical designations. Thus, the motor area—which on stimulation causes movement of skeletal muscles—is known as area 4; the adjacent premotor region as area 6; another area which on stimulation moves the eyes is numbered 8, etc. The map in Fig. 2 gives these numerical designations as modified by Dusser de Barenne; the capital letters L, F and A denote respectively Leg, Face and Arm, so that area L.4 is the leg area and A.6 the part of the premotor area concerned with the arm, etc.

(*Motor fields* (*Areas 4 and 6*)

The excitable characteristics of these areas has already been described, *i. e.*, a mosaic of discrete foci can readily be demonstrated. When these areas are ablated in monkeys or chimpanzees, an enduring paralysis occurs; indeed, if areas 4 and 6 (including leg, arm and face) are destroyed bilaterally in an adult monkey, the animal is as gravely paralyzed as when both cerebral hemispheres are removed (Bieber and Fulton, 1938). This means not only that the motor functions are encephalized to this surprising extent in higher primate forms, but it also indicates that they are *localized* to a given rather small area within the cerebral hemisphere. This localization is far less discrete in the lemuroids than in the pithecoids.

In the adult pithecoid the functional localization of motor patterns is so complete that enduring volitional paralysis follows bilateral ablation of particular regions. But this is not true of young animals of the same species. You are familiar with the biological concept that ontogeny tends to repeat phylogeny, *i. e.*, that embryological development is on its broad outline a recapitulation of evolutionary history. It is undoubtedly, therefore, a fact of prime importance that when the motor and premotor areas are removed from monkeys shortly after birth, as has been done in the recent studies of Dr. Margaret Kennard (1938), the baby pithecoids behave much as do *adult* galagos and pottos after a similar lesion, *i. e.*, they have only slight motor paralysis. However, as these baby macaques grow older, signs of deficit begin to appear; but they never become as grave as the paralyses which follow a corresponding ablation in an adult animal. There exists in the infant nervous system of a pithecoid monkey, greater capacity to reorganize its functional localization, *and the pithecoid infant behaves as if it were an adult lemuroid.*

Dr. Kennard is much interested at the moment in attempting to discover what part of the nervous system is responsible for integrating movement patterns of her normal infant macaques. The basal ganglia undoubtedly play an important role; but during the first six months of life their function is gradually taken over by the cerebral cortex. In these young animals, therefore, as in the human infant, the evolutionary process of encephalization proceeds under our very eyes.

Considerations of space forbid more detailed discussion of the other cytoarchitectural areas of the cerebral cortex, but in the case of all those which have been fully investigated a corresponding increase of functional discreteness has been established as the primate scale is ascended. In the tarsioids and lemuroids the cerebral cortex is smooth and only the major fissures—such as the Sylvian—can be identified; the boundaries of lemuroids are more indefinite functionally and anatomically than in the pithecoids. The insectivors and rodents have a similarly smooth cortex with even less discreteness of functional localization, and this has no doubt been responsible for a modern error among experimental psychologists who, until very recently, have insisted in the equipotentiality of all regions of the cortex. In so far as "learning" is concerned there may be a basis for their contention—and this is true of man as well as animals—but when one scrutinizes the great sensory and motor functions of the primate forebrain the concept of equipotentiality is not only one of harmony with every known fact of comparative neurophysiology, but it is in addition naive and misleading.

The functional approach to the evolution of the primate brain has thus given clarity and precision to doctrines which in the past have been based largely upon inferences drawn from morphological studies.

REFERENCES

Aldini, G. Essai theorique et experimental sur le galvanisme. Paris, 1804. x, 398 pp., 4 pl.

Beevor, C. E., and **Horsley, V.** A record of the results obtained by electrical excitation of the so-called motor cortex and internal capsule in an orang-outang (*Simia satyrus*). Philos. Trans., 1890, **181 B**: 129–158.

Bieber, I., and **Fulton, J. F.** The relation of the cerebral cortex to the grasp reflex and to the postural and righting reflexes. Arch. Neurol. Psychiat., Chicago, 1938, **39**: 435–454.

Brodmann, K. Vergleichende Lokalisationslehre der Grosshirnrinde in ihren Prinzipien dargestellt auf Grund des Zellenbaues. Leipzig, J. A. Barth, 1909; reprinted, 1925, xii, 324 pp.

Catchpole, H. R., and **Fulton, J. F.** Tarsiers in captivity. Nature, 1939, **144**: 514.

Clark, W. E. LeGros. Notes on the living tarsier (*Tarsius spectrum*). Proc. Zool. Soc. Lond., 1924, 217–223.

Clark, W. E. LeGros. Early forerunners of man. A morphological study of the evolutionary origin of the primates. London, Balliere, Tindall and Cox, 1934, xvi, 296 pp.

Connolly, C. J. The fissural pattern of the primate brain. Amer. J. Phys. Anthrop., 1936, **21**: 302–422.

Connolly, C. J. Development of the cerebral sulci. Amer. J. Phys. Anthrop., 1940, **26**: 113–149.

Cook, Norman. Notes on a group of tarsiers in captivity. J. Mammol., 1939, **20**: 173–178.

Cushing, H. A note upon the faradic stimulation of the postcentral gyrus in conscious patients. Brain, 1909, **32**: 44–53.

Dusser de Barenne, J. G., and **McCulloch, W. S.** Functional organization in the sensory cortex of the monkey (*Macaca mulatta*). J. Neurophysiol., 1938, **1**: 69–85.

Ferrier, D. The Croonian Lecture. Experiments on the brain of monkeys (second series). Philos. Trans., 1875, **165**: 433–488.

Ferrier, D. The functions of the brain. London, Smith Elder and Co., 1876, xv, 323 pp.

Foerster, O. The motor cortex in man in the light of Hughlings Jackson's doctrines. Brain, 1936, **59**: 135–159.

Fulton, J. F., and **Dusser de Barenne, J. G.** The representation of the tail in the motor cortex of primates, with special reference to spider monkeys. J. cell. comp. Physiol., 1933, **2**: 399–426.

Fulton, J. F., and **Keller, A. D.** The sign of Babinski. A study of the evolution of cortical dominance in primates. Springfield, Ill., Charles C. Thomas, 1932, xv, 165 pp.

Grunbaum, A. S. F., and **Sherrington, C. S.** Observations on the physiology of the cerebral cortex of some of the higher apes. Proc. Roy. Soc., 1901, **69**: 206–209.

Hall, M. On the reflex function of the medulla oblongata and medulla spinalis. Philos. Trans., 1833, **123**: 635–665.

Harrison, R. G. On the occurrence of tails in man, with a description of the case reported by Doctor Watson. Proc. Ass. Amer. Anat., 1901, **14**: 141–148.

Hilgard, E. R., and **Marquis, D. G.** Conditioning and learning. New York, D. Appleton-Century Co., 1940, xii, 429 pp.

Hitzig, G. Untersuchungen uber das Gehirn. Berlin, A. Hirschwald, 1874, vi, 276 pp.

Kennard, Margaret A. Alteration in response to visual stimuli following lesions of frontal lobe in monkeys. Arch. Neurol. Psychiat., Chicago, 1939, **41**: 1153–1165.

Kennard, Margaret A. The relation of age to motor impairment in man and sub-human primates. Arch. Neurol. Psychiat., Chicago, 1940, **40**: 377–397.

Lashley, K. S. Studies of cerebral function in learning. XI. The behavior of the rat in latch box situations. The mechanism of vision. XII. Nervous structures concerned in the acquisition and retention of habits based on reactions to light. Comp. Psychol. Mongr., 1935, **11** (no. 52), 79 pp.

Leyton, A. S. F., and **Sherrington, C. S.** Observations on the excitable cortex of the chimpanzee, orang-utan and gorilla. Quart. J. exp. Physiol., 1917, **11**: 135–222.

Linné, C. von. Systema naturae, sive regna tria naturae systematica proposita per classes, ordines, genera, et species. (1st ed.) Leyden, T. Haak, 1735, 14 fol.

Linné, C. von. Systema naturae per regna tria naturae secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. . . . 2 vol. (10th ed.) Stockholm, L. Salvius, 1758–59.

Malmo, R. B. Effects of removal of the visual cortex on brightness discrimination and spectral brightness distribution in the rhesus monkey. Dissertation, Yale University, 1940.

Marquis, D. G. Effects of removal of the visual cortex in mammals, with observations on the retention of light discrimination in dogs. Res. Publ. Ass. nerv. ment. Dis., 1934, **13**: 558–592.

Marquis, D. G. Phylogenetic interpretation of the functions of the visual cortex. Arch. Neurol. Psychiat., Chicago, 1935, **33**: 807–815.

Matthew, W. D. The evolution of mammals in the Eocene. Proc. zool. Soc. Lond., 1928, 947–985.

Mott, F. W., and **Kelley, Agnes M.** Complete survey of the cell lamination of the cerebral cortex of the lemur. Proc. Roy. Soc., 1908, **80 B**: 488–506.

Mott, F. W., Schuster, E., and **Halliburton, W. D.** Cortical lamination and localisation in the brain of the marmoset. Proc. Roy. Soc., 1910, **82 B**: 124–134.

Penfield, W. G., and **Boldrey, E.** Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. Brain, 1937, **60**:389–443.

Ruch, T. C., Fulton, J. F., and **German, W. J.** Sensory discrimination in monkey, chimpanzee and man after lesions of the parietal lobe. Arch. Neurol. Psychiat., Chicago, 1938, **39**: 919–937.

Ruch, T. C. Cortical localization of somatic sensibility. The effect of precentral, postcentral and posterior parietal lesions upon the performance of monkeys, trained to discriminate weights. Res. Publ. Ass. nerv. ment. Dis., 1935, **15**: 289–330.

Schrader, M. E. G. Zur Physiologie des Vogelhirns. Pflug. Arch. ges. Physiol., 1889, **44**: 175–238.

Sherrington, C. S. Notes on the arrangement of motor fibres in the lumbro-sacral plexus. J. Physiol., 1892, **13**: 621–772.

Stock, Chester. An Eocene primate from California. Proc. Nat. Acad. Sci. Wash., 1933, **19**: 954–959.

Stock, Chester. A second Eocene primate from California. Proc. Nat. Acad. Sci. Wash., 1934, **20**: 150–154.

Volsch, M. Ein Rindenreizungsversuch an einem Halbaffen. Mschr. Psychiat. Neurol., 1906, **20**: 470–471.

Vogt, C., and **Vogt, O.** Sitz und Wesen der Krankheiten im Lichte der topistischen Hirnforschung und des Variierens der Tiere. J. Psychol. Neurol., Lpz., 1936, **47**: 237–238.

Woodward, A. S., Smith, G. Elliott, Hill, J. P., Wood-Jones, F., Pocock, R. I., Cunningham, J. T., Mitchell, P. C., and **MacBride, E. W.** Discussion on the zoological position and affinities of *Tarsius*. Proc. zool. Soc. Lond., 1919, **19**: 465–498, 1 pl.

Woollard, H. H. The cortical lamination of *Tarsius*. J. Anat., Lond., 1925, **60**: 86–105.

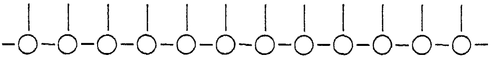
Woollard, H. H. The anatomy of Tarsius spectrum. Proc. zool. Soc. Lond., 1935, 1071–1184.

A SCALED MODEL OF A PROPOSED PROTEIN STRUCTURE[1]

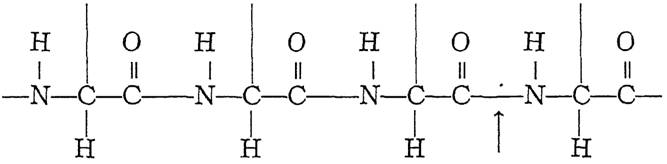
EDWARD MACK, JR.
University of North Carolina and Battelle Memorial Institute

This little article is intended to give a brief view of our present quite imperfect picture of protein molecule structure, and is addressed particularly to some of the geometrical aspects of the situation.

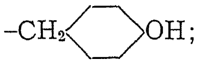
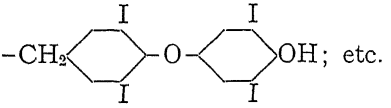
In a certain sense it is possible that the structure of the protein molecules is very simple. According to the classical theory, based largely on Emil Fischer's work, a protein molecule is a chain-like structure, the nature of which may be indicated in the following manner:



where the members of the chain are amino acid residues. The small circles, or heads, are the same for all amino acids (we shall pass over the imino acids). They are joined together by the "peptide" bond, formed by splitting off water between the $-COOH$ group in the head of one amino acid and the $-NH_2$ group in the head of a neighboring amino acid, thus:



peptide bond

The tails, or side chains, are different for different amino acids. For glycine, the side chain is $-H$; for alanine $-CH_3$; for lysine $-CH_2CH_2CH_2CH_2NH_2$; for tyrosine ; for thyroxine ; etc. About twenty-four different amino acids seem to be important in animal metabolism, although a few others are known.

---

[1] The model described here was first presented at a Symposium at the Richmond Meeting of the American Association for the Advancement of Science in December, 1938; and again at the Columbus Meeting of the Ohio Academy of Science in May, 1940.

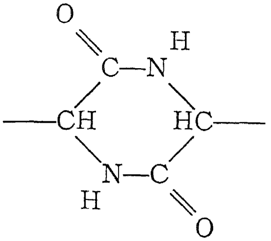
In another sense of the word, protein structure may be considered as not at all *simple*. The average molecular weight of the amino acid is about 120. Since the molecular weight of various proteins range from perhaps about 34,000 up to 100,000,000 or more, it is obvious that a very large number of amino acid residues are present in such giant molecules. It has been suggested that the many shades of physical and chemical properties, which the proteins are known to possess, are to be accounted for not only by the actual total number of amino acid residues present, and by the particular kinds of residues present, and by their relative population but also by the nature of their sequence along the molecule backbone. A chain -GGGAAAGGGAAA-, where G and A represent glycine and alanine, might well produce an entirely different set of behaviors than the arrangement -GAGAGAGAGAGA-. With only a few different amino acids in a backbone which is merely a few hundred links long, the number of possible permutations is, of course, immensely large. It seems likely, too, that a regularly repeated order of arrangement would lead to quite different properties than a random one.

Bergmann (1) and others have, in fact, shown that the amino acids are probably arranged in some definite order, in natural protein molecules, and in some cases it has now been possible to deduce the sequence. "Living organisms therefore do not achieve the synthesis of the immense number of proteins provided by the peptide theory in its original conception, but seem to synthesize only those proteins that exhibit— simple numerical rules. The discovery of the quantitative rules governing the protein molecule makes the biological synthesis of an individual protein molecule appear as a process which involves a specificity that is both highly delicate and extremely complex. Such specificity phenomena are a clear indication of the operation of an enzymatic process which directs all the steps involved in the synthesis of the special pattern of each individual protein."

STRING, SHEET AND BODY STRUCTURES

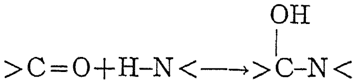
There is reasonably good evidence for the conclusion that some protein molecules exist as strings, others as sheets or as 3-dimensional lumps of some sort. It is not unlikely that a given molecule may assume all of these shapes in different settings. Long ago, for example, Dr. Nouy (2) estimated the size and shape of certain protein molecules lying in a water surface, and concluded that they were tiny cylinders or prisms, probably formed by the coiling up of the long string-like molecules. Mirsky and Pauling (3) have pointed out that the well-defined properties of native proteins require that their molecules have definite configurations. Whether such protein molecules, lying alongside one another, are joined together laterally by chemical bonds (somewhat after the manner of vulcanized rubber molecules), or by hydrogen bonds, or by van der Waals forces, strong or weak, is a question to which we would like to have an unambiguous answer.

In this connection, an extremely interesting theory has been advanced by Dr. Wrinch (4)—the cyclol fabric. It is supposed that two amino acid molecules unite to form a closed diazine ring, by splitting off water as in the formation of the peptide bond:



The formation of such a hexagonal ring is plausible. Indeed, if the two side chains are H atoms, this diazine ring is diketopiperazine, which is known to exist. Corey (5), by X-ray examination of the crystal, has found that the diketopiperazine rings are flat, and that they are joined together by hydrogen bonds in long strings.

Now, according to the early Wrinch theory, these diazine rings unite chemically with one another by the reaction



$$>C{=}O+H\text{-}N<\longrightarrow>\overset{\overset{OH}{|}}{C}\text{-}N<$$

to give a structure, in which three diazine rings meet in a triazine ring, and which by extension in space yields the so-called cyclol fabric (Figure 1) a sheet-like structure. Further, it is supposed that the fabric can fold into a "cage," which is a truncated regular tetrahedron. Pictures of the model of this structure are shown in some of Dr. Wrinch's papers, but will not be reproduced here. The smallest cage of this type contains 72 amino acids, and the larger ones $72\text{x}2^2$, $72\text{x}3^2$, $72\text{x}4^2$, etc. Since the average molecular weight of amino acids is about 120, the molecular weights of these protein cage molecules (forgetting the smallest) would be about 34,000, 76,500, 136,000, etc. This seems to be in remarkably close accord with the actually observed non-random distribution of molecular weights; although an alternative explanation which has been offered is that chain molecules of certain definite lengths, with none in between, may be formed because of the nature of the act of protein synthesis.

SCALED MODEL OF CYCLOL FABRIC

While, as already stated, the formation of the diazine rings is plausible, a very serious difficulty confronts the hypothesis that these rings can join together to form the fabric. The difficulty can be shown with the aid of a scaled model (Figure 2).

The central carbon atom of the heads of the amino acids, with the exception of glycine, are all assymetric, and happen to be of the l-variety. As a direct consequence of this, the nests of three OH groups on the alternate triazine rings are located above and below the plane of the fabric (see Figure 1), whereas the side chains are all above the plane. Half of the side chains are disposed "initially upwards," the other half "initially outwards" as shown in Dr. Wrinch's diagram (Figure 1) and correspondingly shown in Figure 2 by the match sticks (which represent the side chains).

The model is made on a scale of 10^8 to 1, or 1 cm.≡A°. The C–C internuclear distance is taken as 1.54, C–N as 1.47, C–H as 1.08, C–O as 1.43, and O–H as 0.97. The diameter of the hydrogen atom (more acceptably set at 2.13 or larger) is shaded down, for the sake of the argument, to 2.0; that is, the domain radius of the hydrogen atoms, beyond the nucleus, is made to be 1.0. This is in substantial accord with the value estimated (6) from the crystal lattices of methane and ethane, and with the size needed to account for the cross-sectional areas of hydrocarbon chains in crystals and in oil films. The angle of the oxygen bonds is taken as 111°, the carbon bonds are tetrahedral, and I have allowed myself the license of making the angles of the three bonds of the nitrogen atom 109½°. (The angles are probably more like 108°). This license permits the assembly of the model as a "puckered" planar sheet, and amounts really to only a very small concession in the direc-

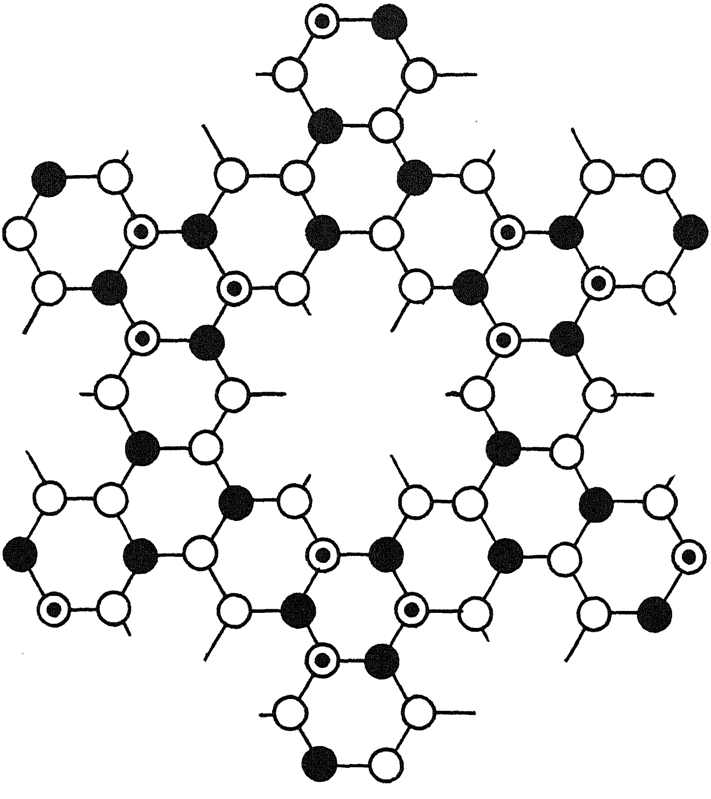


Fig. 1. A fragment of the cyclol fabric. Solid symbols represent nitrogen. Hollow symbols represent C(OH), hydroxyl upwards. Hollow symbols with dot in center represent C(OH), hydroxyl downwards. Hollow symbols with long arm represent CHR, direction of side chain initially outwards. Hollow symbols with short arm represent CHR, direction of side chain initially upwards.

tion of conforming with Dr. Wrinch's practice. As a matter of fact, as far as the conclusion regarding the plausibility of the cyclol fabric is concerned, one can increase or decrease the bond angles by many degrees, without affecting the final clear cut conclusion.

One difficulty lies in the region of the fabric indicated by the white arrow in Figure 2. The three hydroxyl groups (shown here with oxygen atoms to scale) find sufficient room on the triazine rings for their accommodation, either as formal OH groups, or with the H atoms resonating between pairs of O atoms. But the three "initially upward" side chains surrounding the rest of hydroxyls are very severely crowded for space.

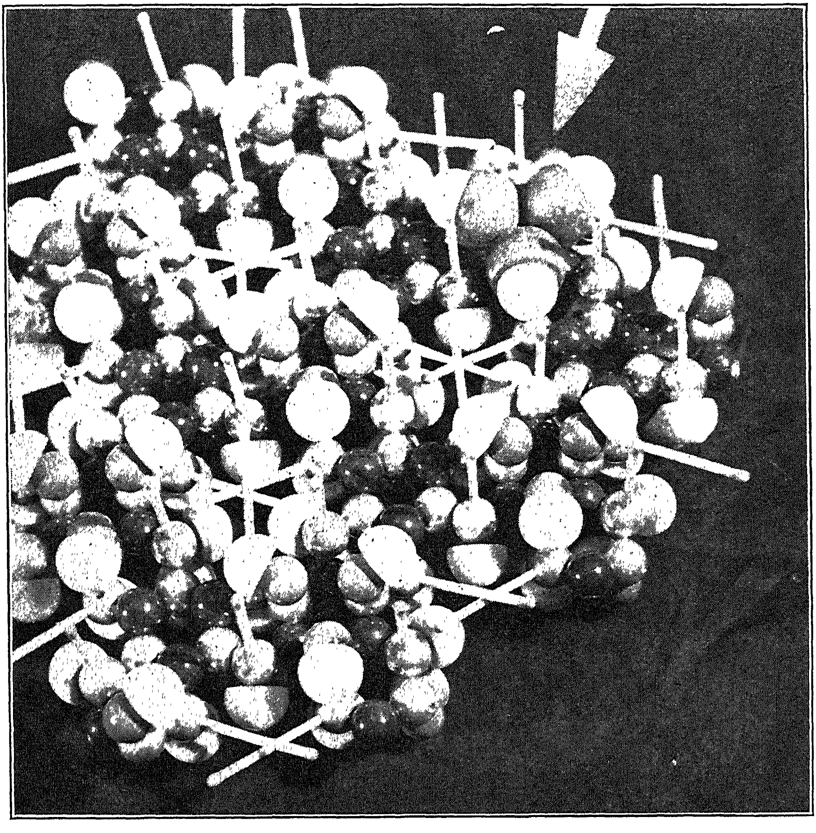


Fig. 2. View of model from above.

A far more serious difficulty involves the "initially outward" side chains. Three of these extend into the central hexagonal cavity of Figure 1, and are shown as three crossed match sticks in the corresponding cavities of Figure 2. Now, it is to be borne in mind that these match sticks represent side chains which, on the model scale, are at least as bulky (with the exception of glycine) as normal hydrocarbon chains, and in some of the amino acids they are as bulky as benzene rings (tyrosine and thyroxine, for example). It is obviously simply physically impossible to pack so much matter into so small a space.

Figure 3, which is Figure 1 reproduced more nearly to proper atomic scale, shows the difficulty clearly. HHH are the three hydrogen atoms which are carried by the same carbon atoms to which the three vertical ("initially upward") side chains, around the rim of the cavity, are also

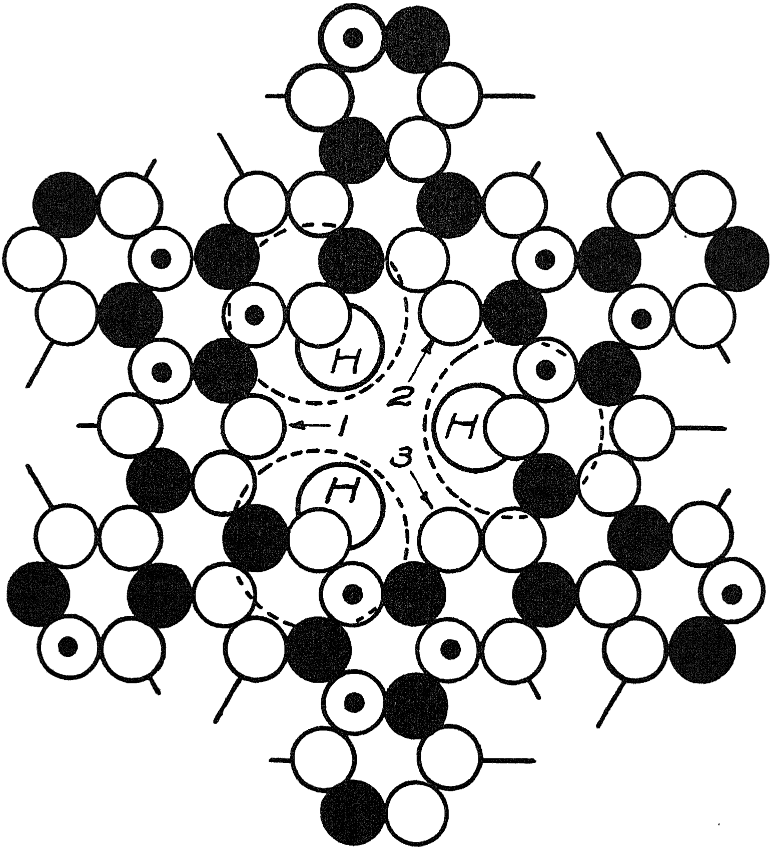


Fig. 3. Fragment of cyclol fabric drawn roughly to scale to show extremely small relative size of hexagonal cavity.

attached. The large dotted circles show the minimum space occupied by these vertical side chains of about 18 sq. A°. The points where the side chains "initially outwards" are supposedly attached are indicated by 1, 2, 3. The free space left in the hexagonal cavity, into which these three "initially outward" side chains are supposed to protrude, from their points of attachment to three carbon atoms bordering the cavity, and out of which they must extend and reach up (or down) to the surface in some way, is barely large enough to accommodate a single extra hydrogen atom. Only if the three hydrogen atoms HHH were entirely removed *and* only if the three *vertically* placed side chains were entirely removed, would the free space of the cavity take care of a *single* normal hydrocarbon chain; and many of the amino acid side chains are larger in cross-section than a hydrocarbon chain, and furthermore *three* side chains are to be accommodated.

The protein fibroin is said to contain glycine to the extent of about 50% of its amino acid residues (1). It is conceivable that the Wrinch fabric could account satisfactorily for it and other possible proteins of at least 50% glycine content, *if* all of the glycine hydrogens were to occupy the "initially outward" positions, and *if* the "initially upward" side chains could also be attached to the fabric. The difficulty is that most proteins seem to contain much less than 50% glycine residues and many contain none at all.

Huggins (7) has already called attention to these space difficulties, as have also Neurath and Bull (8). Pauling and Niemann (9) have shown the improbability of the formation of the cyclol fabric on the grounds of energy considerations.

Hydrogen bond linkage of the diazine rings has been suggested (10), and more recently Dr. Wrinch (11) has described a modified fabric in which instead of a lactam-lactim there is a keto-enol transformation. But still the available space is far from adequate to permit the proposed disposition of the side chains. Huggins (12) has also made some further suggestions, which deserve consideration.

It is with regret that one feels compelled to abandon the cyclol fabric and its close cousins. Many of the attractive features of the cyclol fabric theory have been set forth by Langmuir (13). Dr. Wrinch's speculations have been immensely stimulating to those interested in protein structure, and it is still possible that her general picture of protein structure is not far from the truth. The objections raised here are directed against the specific cyclol fabrics which have been suggested.

On the other hand, we should not forget that a satisfactory accounting for the facts of protein behavior may very likely be rendered by a development and extension of the classical theory of long chain peptide structure; and as illustration of such an extension the recent fascinating and suggestive paper of Pauling (14) on "A Theory of the Structure and Process of Formation of Antibodies" may be cited.

REFERENCES

(1) **Bergmann.** Chem. Rev., **22,** 423 (1938).
(2) **Du Nouy.** Phil. Mag., **48,** 264 (1924).
(3) **Minsky and Pauling.** Proc. Nat. Acad. Sci., **22,** 439 (1936).
(4) **Wrinch.** Nature, **137,** 411 (1936); Proc. Roy. Soc. London, **160,** 59 (1937); etc.
(5) **Corey.** J. Am. Chem. Soc., **60,** 1598 (1938).
(6) **Mack.** J. Am. Chem. Soc., **54,** 2141 (1932).
(7) **Huggins.** J. Am. Chem. Soc., **61,** 755 (1939).
(8) **Neurath and Bull.** Chem. Rev., **23,** 391 (1938).
(9) **Pauling and Niemann.** J. Am. Chem. Soc., **61,** 1860 (1939).
(10) **Wrinch and Lloyd.** Nature, **138,** 758 (1936).
(11) **Wrinch.** Phil. Mag., **30,** 64 (1940).
(12) **Huggins.** J. Chem. Phys., **8,** 598 (1940).
(13) **Langmuir.** Proc. Phys. Soc. London, July (1939).
(14) **Pauling.** J. Am. Chem. Soc., **62,** 2643 (1940).

ECOLOGICAL FACTORS AND DROSOPHILA SPECIATION

WARREN P. SPENCER,
College of Wooster

INTRODUCTION

In 1927 there appeared H. J. Muller's announcement of the artificial transmutation of the gene. This discovery was received with enthusiasm throughout the scientific world. Ever since the days of Darwin biological alchemists had tried in vain to induce those seemingly rare alterations in genes which were coming to be known as "the building stones of evolution." In the same year Charles Elton published a short book on animal ecology. It was received with little acclaim. That is not surprising. To the modern biologist ecology has seemed a bit out-moded, rather beneath the dignity of a laboratory scientist. Without detracting from the importance of Muller's discovery, in the light of the developments of the past 13 years we venture to say that Elton comes nearer to providing the key to the process of evolution than does radiation genetics.

Here is a quotation from Elton's chapter on ecology and evolution. "Many animals periodically undergo rapid increase with practically no checks at all. In fact the struggle for existence sometimes tends to disappear almost entirely. During the expansion in numbers from a minimum, almost every animal survives, or at any rate a very high proportion of them do so, and an immeasurably larger number survives than when the population remains constant. If therefore a heritable variation were to occur in the small nucleus of animals left at a minimum of numbers, it would spread very quickly and automatically, so that a very large porportion of numbers of individuals would possess it when the species had regained its normal numbers. In this way it would be possible for non-adaptive (indifferent) characters to spread in the population, and we should have a partial explanation of the puzzling facts about closely allied species, and of the existence of so many apparently non-adaptive characters in animals. . . . Finally what little we know about the regulation of numbers in animals enables us to say that the problem of the origin of species can only be successfully solved by the aid of work on numbers."

Two extreme views of the dynamics of evolution appear almost equally inadequate. Among paleontologists it has seemed popular to consider the evolving species as represented by one plastic individual projected indefinitely through time, molded into new form by the direct action of the surrounding environment. In contrast the theory of natural selection sets forth the premise that evolution is brought about by the action of selective factors on a population indefinitely large and in breeding equilibrium. Actually in any species there occur populations, finite in size, fluctuating possibly in rhythm with some climatic factor, and also fluctuating arhythmically in size in response to variable arhythmic ecological factors and combinations thereof. In fact the general rule is irregularity and non-predictable variability. Thus the rise and fall of gene frequencies and the fixation or elimination of certain types are determined or conditioned by a set of variables that differ both in space and in time.

SPECIATION IN DROSOPHILA

To many biologists Drosophila means a small yellow fruit-fly, the species melanogaster. This, indeed, is the most famous of the lot, and used far more than any other for the investigation of genetic and cytological problems. However, the genus contains a great many other forms. From published descriptions and correspondence with collectors I have recently made out a list (certainly not complete) of 72 distinct types of Drosophila collected within the boundaries of the U. S. A. Over half of these we have had in culture in the laboratory at Wooster. Harrison Stalker and I have taken 26 species in Ohio.

One of the hoary arguments of the anti-evolutionist has been that never are new species seen to arise from old ones. By defining species as that group of individuals which can breed and produce fertile offspring the argument was properly sewed up in a neat scrap of fundamentalist logic. If, however, an array of cases can be presented within a group such as Drosophila, and shown to be seriated in regard to degrees of incompatibility between parental stocks and sterility of the hybrids, the case seems to be almost as strong for the occurrence of speciation as if one might sit quietly by and watch the whole business. And some study of the situation leads to the impression that probably the only reason we don't see the process is that we are too impatient to sit that long, or too undiscerning to see what is happening.

An examination of the genus indicates that not all species are equally dissimilar in morphological and physiological characters. Sturtevant (1939) has recently made a thorough study of the living species then available to him (over 40 in all) and on the basis of 27 characters for which each form was analyzed has proposed three sub-genera. Within these sub-genera sections are recognized. Thus the genus falls into groups of what appear to be more or less closely related species. At present immunological studies are projected or in progress in certain laboratories as a further check on these relationships. Although Drosophila of many species had been worked on much earlier, five years ago hybrid crosses had been secured only in the cases of simulans by melanogaster, pseudo-obscura A by B, and both races of pseudo-obscura by miranda. Two years ago in addition azteca had been crossed to athabasca, virilis virilis to virilis americana, and affinis affinis to affinis iroquois, seven cases in all. Today 20 cases of hybridization between diverse types are known in this genus.

Theoretically it would seem possible to seriate the differences or divergences between pairs of Drosophila types, so that it could be stated that these two were closely similar, a second pair more distinct, and a third even less alike, and so on. Actually in Drosophila an attempt may be made to seriate in terms of morphology, physiology and behavior, sexual reactions, gonial chromosomes, salivary chromosomes, geographical distribution, etc. A man-made scheme would no doubt see to it that all fell neatly into the same order of seriation under the several criteria mentioned. Actually by no stretch of the investigator's best scientific imagination can this be done. A little reflection may lead to the conclusion that this is a normal state of affairs if the course of evolution is actually determined by a complex of interacting forces.

Following Dobzhansky's definition of species as that stage of the evolutionary process, "At which the once actually or potentially interbreeding array of forms becomes segregated in two or more separate arrays which are physiologically incapable of interbreeding," we might attempt to arrange a series with regard to inter-type incompatibility and hybrid sterility. Difficulties in the way of applying the above definition of species and in seriation in this respect will appear presently. Not only do inter-group incompatibility and hybrid sterility, both factors in the physiological isolation called for by Dobzhansky's definition, frequently if not generally differ fundamentally in their causes and operation, but there is no uniform rule in regard to their relative strength in various cases. Further, there is sometimes great variation in the incompatibility of several strains of form A with one strain of form B, though all the strains of form A are highly compatible inter-se. Both incompatibility and hybrid sterility, but particularly the former, are highly susceptible to culture conditions. Darwin (1859) in his chapter on hybridism puts the case most clearly in these words, "It is certain on the one hand, that the sterility of various species when crossed is so different in degree and graduates away so insensibly, and, on the other hand, that the fertility of pure species is so easily affected by various circumstances, that for all practical purposes it is most difficult to say where perfect fertility ends and sterility begins. I think no better evidence of this can be required than that the two most experienced observers that ever lived, namely Kölreuter and Gärtner, arrived at diametrically opposite conclusions in regard to some of the very same forms. It is also most instructive to compare the evidence advanced by our best botanists on the question whether certain doubtful forms should be ranked as species or varieties, with the evidence from fertility adduced by different hybridizers, or by the same observer from experiments made during different years. It can thus be shown that neither sterility nor fertility affords any certain distinction between species and varieties." This quotation is given not because it is from Darwin, but because it states the case with a clarity to be looked for in vain in the writings of some modern students of this subject. Quantitative tables giving in per cents the sterility, incompatibility, or fecundity of first crosses and hybrids in Drosophila speciation studies have appeared and will continue to appear (the author is guilty of having perpetrated some of them; Spencer 1940a). They give a false impression of accuracy in the quantitative measurements of factors which are actually extremely susceptible to fluctuations in the environmental set-up and to hereditary variations difficult of analysis by which several strains of a given form may differ.

Through recent hybridization studies which have been reviewed elsewhere (Spencer, 1940b), it is becoming increasingly clear that this genus contains a vast array of recognizably distinct forms, some distantly and others closely related. However, as we seem to approach an analysis of the problems of phylogeny and to be in a position to arrange forms according to their natural affinities, disturbing questions arise. Which are the more nearly related, two stocks which have for a long time period been separated by some effectual isolating mechanism and yet which show little difference in morphology and physiology, or two forms which have more recently diverged but have undergone rapid changes in that part of the genotype which conditions morphological and physiological differences easily recognized? Are two forms living under conditions where the total metabolism of the species is low to be considered more closely related than two forms which live in the tropics even though both pairs have been effectively isolated for the same length of time? In fact the closer one approaches an analysis the less certain does an exact objective description appear possible. It would seem that the dynamic pattern of evolution projected through time could not possibly be accurately described in terms of the static pattern of evolution in space. Perhaps the sooner we realize that we are chasing a will-o'-the-wisp in attempting to arrange the forms of life in a static hierarchy of phylogenetic relationships the better. However, in the light of recent progress I should judge that we are on the verge of finding out much more about evolution than we have known. The taxonomist will continue to have an important, in many cases the most important, role to play in facilitating the study of groups of animal and plant organisms.

It appears that the changes which result in evolution are primarily changes which occur in the structure of the chromatin. A point which may still be considered debatable in some circles is that these changes are discrete and sudden at their primary level, though slow cumulative effects may accrue by gradual and progressive increase in the number of these inherited differences in two diverging stocks. It is unnecessary here to review the variety of processes, structures and characters in living organisms which may be changed by mutation. There is evidence that mutant factors may alter the whole pattern of events in connection with mitosis, may condition increased mutability at other loci, or may favor loss or addition of whole chromosomes. We shall not enter into the controversy as to whether so-called gene mutations are inherently different from small chromosome aberrations. Certainly, and what seems more important, mutation itself may produce slight or profound effects on an organism, may involve one or many so-called loci, may in short provide all sorts of changes which in turn may be combined to give an almost incomprehensible array of permutations. These may conceivably interact with the internal and external milieu in ways innumerable.

That characters by which hybridizing forms of Drosophila differ may be monogenic has already been observed. Pupa case color in Drosophila virilis virilis is gray and in virilis americana is red. A single genetic factor is involved. On the other hand it is not surprising that many of the inter-subspecific differences are multi-factorial. There is no reason at present to believe that any of the characters morphological, physiological, or psychological by which two forms of Drosophila differ are determined by any inherently different mechanism than that which conditions those mutations with which the geneticist has been dealing for some years.

If this thesis be accepted it becomes possible to examine Drosophila populations for differences in gene and chromosomal structure and to consider such differences if found as the basic pattern for the first step in evolutionary divergence. If it be possible to find populations in which single gene or chromosome variants have become fixed it is valid to assume that the case is not inherently different from that in which an ensemble of genetic differences has accumulated and become fixed. We may go further and consider variations in frequency of unfixed genes in different populations to be an earlier and necessary step in evolution. It should be kept in mind that often the mutants with which we work may play a less important role in the development of new types than some which are less conspicuous but more fundamental in the sense that they may be acting to establish an isolating mechanism or to favor the group in natural selection when this becomes a directing factor.

ECOLOGY AND POPULATION MECHANICS IN DROSOPHILA HYDEI

Now, it is high time we get into the field. But being laboratory biologists suppose we shift over to field work by easy stages. Maybe we can learn something in the interim, and at least we can keep from getting our feet wet the first day. I want, therefore, to introduce you to *Drosophila hydei.* We shall go where this beast lives, watch it feed and breed, oviposit, overcome difficulties of temperature and moisture fluctuations. We shall see the eggs dry up one day, others hatch the next day. We shall see masses of semi-liquid medium shimmering in the noon-day sun with the writhing bodies of many thousands of tiny larvae. We shall see older larvae working down below the surface of medium now beginning to dry and later pupating in huge masses in still drier conditions. We shall see hydei die overnight by the tens of thousands, and leave a cold gray and lifeless world in a week or so where once there were literally a million insects breeding and feeding to the limit of the food store. We shall follow a few survivors through perilous days and weeks and months, and see them drop off one by one. We shall finally find the hardier ones and the luckier ones again breeding and see their grandchildren by the million; stark tragedy; the arrows of outrageous fortune; rare good luck; a perfect environment and for a time unlimited expansion with all the checks off; sizzling heat and stiffening cold; larvae drowned out and others dried up and still others coming through, surviving by strange coincidence a whole series of untoward events. This is everyday life for *Drosophila hydei* in any town in the northern part of our United States, and in any town worthy the name there hydei will be.

Drosophila hydei is a tropical species; there is some probability that it originated in Mexico. At least many closely related forms are to be found there. The species has worked northwards through the United States and is now well established in all parts of this country, but always breeding in and about towns and dwelling houses unless temporarily carried out into the open country with garbage or other refuse. In northern latitudes each town forms a potential focus for an "island" population. Such populations pass through several overlapping generations a year with tremendous fluctuations in population size. Even in the mildest winters in this latitude hydei does not overwinter out of doors. The only survivors are those which find refuge in houses, fruit-cellars, restaurants and such places at the time of the first heavy winter freeze. I have followed the course of the hydei population in Wooster for some years. Every month of the winter this fly may be seen in certain restaurants; I have also known it to overwinter in cellars of private homes. It is a robust type, and can live in a dry room, sitting about on the walls for most of the time, provided every day or so it has access to food and moisture for a few minutes. Such an invironment is provided in restaurants; even though there is no opportunity for a winter brood of larvae the adults may carry through from autumn to spring. I have kept adults sufficiently long to be certain of this. In fact the overwintering population is generally in the adult stage. In general the size of a town or village will determine the chance of suitable places for overwintering and of these places being populated at the critical time in the autumn.

Among Drosophila species hydei is not a rapid breeder, the minimum cycle from egg-laying to newly emerged adult being 14 days. To this must be added a minimum of two days for maturing of the female and four days for maturing of the male after eclosion. Thus the life cycle is 18 days for males and 16 days for females under food and temperature conditions optimum for development. Actually the cycle under spring and summer conditions with the diurnal temperature rhythm is in the neighborhood of one month to six weeks.

At this season of the year (May), even though stores of food are available only a few scattered specimens of hydei will be found outdoors. By the middle of June to the first of July thriving colonies of hydei may be observed on garbage heaps, but still the maximum populations for available food are not present. Toward late August and early September the populations will often have built up to a maximum. However, July and August are likely to be hot and dry, and stores of food unless concentrated in large heaps may dry up before a generation of hydei comes through. In Ohio the months of September, October, and November generally see the peak populations of this species built up; particularly is this true during good fruit years, and with moderate autumn precipitation keeping food supply at the proper moisture content. With the heavy freezes generally occurring in late November and early December the hydei population rapidly falls off. Sometimes the species has bred up to such enormous numbers in town that it may be trapped in nearby woods. But this is due to population pressure and not because hydei is capable of establishing itself in natural woodland habitat.

Drosophila hydei is capable of withstanding extremely high temperatures in larval, pupal and adult stages. On a large citrus dump in southern California, containing tons of decaying oranges, grapefruit and lemons, and populated by an adult Drosophila population of many millions, I made a study of temperature tolerance. It had been supposed that a temperature of 30° C., applied even for a few hours, would sterilize male Drosophila. On this citrus dump millions of adult *Drosophila hydei* were surviving with the air temperature a few inches above the surface registering 37° C. for several hours in the heat of the day. It was difficult to determine the exact temperature of the micro-environment forming the three or four millimeter film at the moist surface where the flies were gathered. A peculiar hovering reaction was noted under these conditions. Flies when disturbed flew with extreme rapidity but always in a dense swarm only a few inches above the moist medium and settled back on it quickly. At times the temperature of the medium in which larvae were burrowing was 36° and 37° C. Here many larvae were killed but others survived and when taken into the laboratory pupated normally; the flies emerging were normal and fertile. Thus larvae were observed in great numbers at temperatures at which well over half of them were killed; day after day the survivors had been subjected to these sublethal temperature shocks. I have kept hydei in adult, larval and pupal stages in a room above my garage in Wooster where mid-day temperatures went up to 36° C. *Drosophila hydei* may be the dominant form in summer populations in towns because of its ability to withstand intense heat. However, all species can stand higher temperatures than was formerly supposed. The lethal and sterilizing effects of high temperatures on Drosophila have been due not so much to the direct effect of the temperature as to the gases, particularly carbon dioxide, formed in poorly ventilated culture bottles.

Hydei larvae are also capable of withstanding drying up of food medium, at which time the larvae form small masses resulting in less surface loss of water. If then moist medium is again provided the larvae continue to develop although practically dormant during the drying period. The population pattern of *Drosophila hydei* brought about through the seasonal variations in temperature and moisture, with superimposed temporary and local fluctuations in food supply, moisture, competition with other forms, and temperature supplies the basis for the formation of local races or populations differing from others in the frequency of contained genes.

In a comprehensive series of papers on the mechanics of evolution in Mendelian populations Wright (1931; 1932; 1937) has presented a statistical analysis of the rate of evolution under various hypothetical conditions. For statistical purposes it has been necessary to reduce situations to their simplest terms, far simpler in fact then natural conditions warrant. Wright (1931) states briefly the role which fluctuating conditions may play in the following terms, "A question which requires consideration is the effect of alternation of conditions, large and small size of population, severe and low selection. The effects of changes in the conditions of selection have already been touched upon. Persistence of small numbers or of severe selection for such periods of time as to bring about extensive fixation of factors compromises evolution for a long time following, there being no escape from fixation except by mutation pressure. Many thousands of generations may be required after restoration to large size and not too severe selection, before evolutionary plasticity is restored. Short time oscillations in population number or severity of selection, on the other hand, probably tend to speed up evolutionary change by causing minor changes in gene frequency."

It is possible to make a census of the genetic structure of Drosophila populations for a given year by taking a sample of the population and through inbreeding tests analyzing the genetic variability of the flies. The author (Spencer 1939) has attempted a fragmentary analysis of this sort for two widely separated *Drosophila hydei* populations, one living on a large citrus dump near Azusa, Southern California, and the other in the environs of Wooster, Ohio. The Azusa population is much the larger, perhaps at peak one hundred times the maximum Wooster population. The hot, dry summer at Azusa and the winter in Wooster constitute the critical reduction periods. The analysis has included the collection and examination of over 50,000 wild flies, and the rearing of over 5000 F_2 pair mating broods from some 1200 wild flies from the 1937, 1938, and 1939 Azusa populations, and from the 1937 and 1938 autumn Wooster populations. Inbreeding tests of 100 flies from Gatlinburg, Tennessee, have also been made. More than 180 cases of autosomal recessive mutants carried in wild flies have been found. In addition several sex-linked factors and autosomal dominants have been recorded.

The 1938 Wooster population was characterized by the high concentration of a small group of mutant genes, sex-linked vermilion in .48% of males collected, nicked wings in 4 out of 331 flies tested, gray body in 12 out of 500 flies, scarlet eye in 3 out of 500 flies, and rose eye in 3 out of 331 flies. The Azusa population showed no such high concentration of specific genes. On the other hand a significantly larger number of mutant loci per 100 flies tested were to be found from Azusa than from Wooster. Azusa, Gatlinburg, and Wooster populations have each given a different lot of mutant loci with little overlapping. The samples taken were inadequate to give an accurate quantitative picture of gene frequencies with the exception of vermilion; however, these qualitative results make it possible to plan experiments for adequate quantitative tests of yearly fluctuations in specific gene frequencies.

All over the United States there occur local populations of *Drosophila hydei*, varying in average size with the size of the towns and available food stores, undergoing periodic oscillations as well as arhythmic fluctuations due to ecological factors, and setting the stage for micro-evolution through rise and fall of gene frequencies. There seems little doubt but that here and there throughout this vast array of populations there occur cases of fixation of some mutant type. If this mutation should happen to initiate a partially isolating mechanism an insipient subspecies would be the result.

We have considered the case of *Drosophila hydei* in some detail because of the fact that its close association with man makes it possible to observe its activities more thoroughly the year round. These observations may serve in a way to bridge the gap between strictly laboratory and bona fide field work. We may think of a study of hydei populations as a large scale experiment carried on through the intervention of man but clarifying somewhat the problems to be encountered in studying species breeding in their natural range.

SOME ECOLOGICAL OBSERVATIONS ON OTHER DROSOPHILA SPECIES

If you have the time suppose we do some field collecting. It is the month of May. We go to the Providence mountains, a range in the Mojave desert of Southern California. We climb to the top of the ridge at mid-day. As the sun beats down on stunted pinon pine and bare rocks the temperature mounts well above 100° F. We pick up a club and break open a rotting specimen of *Echinocactus acanthodes*, the California barrel cactus. Inside is a great bowl of cactus soup, alive with Drosophila larvae. The adults sitting around on the inside of this bowl, little yellow fellows, turn out to be *mulleri mojavensis*, a subspecies which can cross with *mulleri mulleri* from Texas. Later we see as we drive along a desert road a belt of barrel cactus at elevations of around 3000 feet, a thin line of supplies but adequate to allow *mulleri mojavensis* to migrate all over the deserts from mountain range to mountain range. We go again up the arroyo, with not a drop of water in sight, in fact not a spring in the entire range. We set out traps in the late afternoon, and soon pseudo-obscura are flying in apparently from an environment as dry as tinder except for a little resin oozing from the pinons. Here and there is that spiny denizen of the desert, *Yucca mojavensis*. We kick over one of these tough plants and at the base find a mass of soft, moist fiber with mold growing in it. Where molds grow yeasts grow and there we find pupae which look suspiciously like those of pseudo-obscura.

We go some hundreds of miles away to Death Valley and drive up the desert floor of the valley during the afternoon. The thermometer registers 110° F. in the shade; but there is no shade. We camp for the night at Mesquite Springs; a clear cool spring running a quart or so of water a minute, a dozen screw-bean trees with gnarled and spreading branches, and plenty of fine soft sand. We hang our traps near the spring and with the aid of a flashlight visit them at night. Temperature readings show the thermometer creeping down toward 30° C., then lower and at around 27° C. the flies begin coming to the traps, first that yellow one we took in the Providence mountains, then a black, shiny one, then a stray pseudo-obscura or two. These last should be far away in the cool of the mountains at this time of year, but here they are. Perhaps they will live out the summer, more than likely not.

It is August and we are back in Ohio. We have set our traps in cool, wooded nooks along a branch of the Killbuck creek. We visit them in the early morning for even in Ohio it will be hot at midday and most of the Drosophila will have left the traps and found a cool spot at the warning of that rapid mid-morning temperature rise. At six or seven in the morning the flies are coming to the traps and we collect two or three thousand in a couple of hours. Back in the laboratory we check them over, the usual ones, perhaps 15 or 20 species. Here are a couple we ought to know, but they don't look quite right. We go to the species stocks and get out macrospina from Texas. The ones in our morning catch have the peculiar genitalia of macrospina but they are away off in eye color, body color and size. They turn out to be a new subspecies, breeding true to their peculiar character but crossing readily with Texas macrospina. We call them *macrospina ohioensis* (Spencer 1940b). Another morning we visit traps set in the swamps. This morning we go early, four-thirty, and we get our feet wet. But we get something else as well. Two new Ohio species; but are they species? They are morphologically distinct with many character differences, but they will cross and their hybrid offspring are partially fertile. They cross with less ease than the macrospinas and we are not sure whether to call them species or subspecies. Somehow we can't seem to think that it makes much difference. On our trips we have taken flies that feed on fungus and others that feed on bleeding trees. We found larvae of the new swamp species feeding on rotting stocks of the arrow-weed.

We might discuss population patterns of flies breeding on leaf mold and humus all over our native woods, of flies confined to swamp habitats, of those which apparently feed mostly on fungus. There is much we do not know of the habits, the distribution, the ecology of these and others. We have a notion that field studies will help to answer some of the problems of speciation in the group. In any case it's a good excuse to be outdoors.

ENVIRONMENTAL FACTORS AND MUTATION

We have considered the action of the ecological pattern on distribution of mutant factors present in populations, resulting in shifts in gene frequencies; sometimes the elimination of mutant genes; at other times their rapid spread and even fixation. But there is more than a remote possibility that ecological factors may play an active role in producing the mutations involved. For many years men attempted to find the key to mutation. Muller finally found one key in X-rays. But he and Mott-Smith (1930) soon demonstrated that short wave radiation played no major role in natural mutation. Others, notably Jollos (1934), Goldschmidt (1929), and Plough and Ives (1935) have shown that sub-lethal heat shocks increase mutation rate. Gottschewski (1934) also demonstrated mutation increase through cold temperature shock. In recent years experiments have been reported, particularly by Russian workers, which indicated a sensible rise in mutation frequency following various other treatments, chiefly chemical. In fact we seem now to be in possession of too many keys. At the present time we may say that we cannot yet be sure that they all fit the lock.

Day after day, week after week, Drosophila in nature are receiving temperature shocks many of which are of the order of magnitude of those used by investigators reporting increase in mutation rate. The possible combinations of shock which might result from fluctuation in temperature, moisture and other ecological factors may conceivably be playing a direct role in determining the rate at which natural mutations are occurring. In fact experiments on wild stocks of *Drosophila melanogaster*, summarily reported in manuscripts received from Russian workers and read at the 7th International Genetics Congress in Edinburgh last summer set forth this point of view in some detail. This position may seem to be less satisfactory than the over-simplified view that some one definite factor could be discovered as the cause of mutation. The more we learn of the nature of the organic world the less chance there seems to be to reduce biology to a system of simple generalizations.

BIBLIOGRAPHY

Darwin, Charles. 1859. On the origin of species by means of natural selection. London. 6th edition, D. Appleton and Co., New York. xxi+458 pp.

Dobzhansky, Th. 1937. Genetics and the origin of species. Columbia Univ. Press, New York. xvi+364 pp.

Elton, Charles. 1927. Animal ecology. Sidgwick and Jackson, Ltd., London. xvii+207 pp.

Goldschmidt, R. 1929. Experimentelle Mutation und das Problem der sogenannten Parallelinduktion. Biol. Zbl. 49: 437–448.

Gottschewski, G. 1934. Untersuchungen an *Drosophila melanogaster* über die Umstimmbarkeit des Phänotypus und Genotypus durch Temperatureinflüsse. Z. indukt. Abstamm. und VererbLehre. 67: 477–528.

Jollos, V. 1934. Inherited changes produced by heat-treatment in *Drosophila melanogaster*. Genetica 16: 476–494.

Muller, H. J. 1927. Artificial transmutation of the gene. Science 66: 84–87.

Muller, H. J. and **Mott-Smith, L. M.** 1930. Evidence that natural radioactivity is inadequate to explain the frequency of "natural" mutations. Proc. Nat. Acad. Sci. 16: 277–285.

Plough, H. H. and **Ives, P. T.** 1935. Induction of mutations by high temperature in Drosophila. Genetics 20: 42–69.

Spencer, W. P. 1939. On the genetic structure of *Drosophila hydei* populations. Genetics 24: 86–87.

1940a. Subspecies, hybrids and speciation in *Drosophila hydei* and *Drosophila virilis*. Amer. Nat. 74: 157–179.

1940b. Levels of divergence in Drosophila speciation. Amer. Nat. 74: 299–311.

Sturtevant, A. H. 1939. On the subdivision of the genus Drosophila. Proc. Nat. Acad. Sci. 25: 137–141.

Wright, Sewall. 1931. Evolution in Mendelian populations. Genetics 16: 97–159.

1932. The roles of mutation, inbreeding, crossbreeding, and selection in evolution. Proc. 6th Int. Congress of Genetics 1: 356–366.

1937. The distribution of gene frequencies in populations. Proc. Nat. Acad. Sci. 23: 307–320.

Grain Pests

This authoritative book fulfills a definite need in economic entomology by bringing together all the information on a subject which heretofore has not been treated in this manner. It is written by one who has many years of experience in the experimental work conducted for the control of stored product pests.

The contents of the book is as follows, by chapters: The Insect Pests of Stored Grain and Milled Cereals; Controlling Stored Grain Insects on the Farm; Control of Insects in Grain Stored in Elevators and Warehouses; The Insect Problem in Flour Mills; Practical Control Methods in the Mill; Protecting Flour after Manufacture; Fumigants and Fumigation; The Common Fumigants; Flour Mill and Warehouse Fumigation; Fumigation in Atmospheric Vaults and Vacuum Chambers; Heat Sterilization in the Flour Mill.

At the end of each chapter is a selected list of references to the subject. An index completes the volume which is printed on heavy white paper by the offset process. The nature of the binding permits the book to remain flat when opened at any page.

It is an excellent contribution to economic entomology and will be a handy reference to the entomologist as well as the farmer, teacher and mill operator.

—*R. H. Davidson.*

Insect Pests of Stored Grain and Grain Products, by Richard T. Cotton. 242 pages. Minneapolis, Minnesota, Burgess Publishing Company, 1941. $3.00.

THE ORIGIN OF OHIO SOILS

GUY W. CONREY,
Ohio Agricultural Experiment Station and
Ohio State University

The soils of any region owe their character primarily to the conditions of environment under which they have developed. Just as in the biological world, also in rock weathering and in soil development, the key note is adaptation to environment. When rock material is exposed at the surface changes take place with the production of compounds which are more stable under that environment. Moreover, any change in environment will result in changes toward compounds which are more stable under the new conditions.

Factors of major importance in soil development include parent material, climate, vegetation, topography and drainage, and age. This is sometimes expressed in the form of an equation(1)[1]:

$$\text{Soil} = \gamma\ (\text{climate, vegetation, relief, age, parent rock})$$

If soil material stays in place for a sufficient time for the environment to be impressed on it, the result is expressed or shown in the development of layers or horizons differing in characteristics, such as color, texture, structure, consistency, etc., from the surface downward. This succession of horizons makes up the *soil profile.*

For information concerning soil material—parent material—we turn to our geologists. First, the bedrock of Ohio is everywhere sedimentary. West of a line drawn from Sandusky through Columbus the underlying rock is largely limestone, to the east sandstone and shale predominates. Actually much of the sandstone is in reality a siltstone—a very fine grained sandstone which weathers to silt.

Throughout about two-thirds of the state the surface materials are glacial in origin. The local character of the drift is shown in that 75 per cent or more is made up of material transported less than 25 miles. In western Ohio then, there is glacial limestone material, in northeastern and east central areas glacial sandstone and shale material. In northwestern Ohio and a narrow belt bordering Lake Erie in northeastern Ohio, the soil material is largely glacio-lacustrine in origin.

Beyond the glacial border in southern and southeastern Ohio the soil material is predominantly residual in origin. Its character depends on the nature of the local rocks—limestone and calcareous shale in Adams County in southern Ohio, and sandstone and shale in southeastern counties, except locally where limestone may be important; elsewhere red clay shale.

Climate is of first importance as an environmental factor in soil development. The most important climatic factors are rainfall and temperature, along with humidity and length of the frost free period.

---

[1] Numbers in parentheses refer to literature cited at end of paper.

Of special importance in soil development is the amount of water actually percolating through the soil. The actual soil climate will be conditioned by the slope of the land and the vegetative cover. The total rainfall, then is not an important factor, rather the effective moisture after losses by runoff and evaporation have been taken into account.

Transeau (2) in 1905 suggested the rainfall-evaporation ratio as an index to precipitation efficiency. Although records of evaporation were very limited, the concept was fundamental, and has been very helpful in evaluating climates. In 1935 Transeau stated that evaporation data was still very meager.

In the absence of data on evaporation, several attempts have been made to evaluate this factor from temperature records. Lang (3) in Germany in 1915 suggested the Rain Factor (annual precipitation in millimeters divided by mean annual temperature in degrees centigrade). The fundamental concept, that evaporation varies directly with mean annual temperature, does not agree with facts. Meyer (4), also in Germany, in 1926 used the N-S-Q value—the N-S quotient, that is precipitation in millimeters divided by the saturation deficit. The latter (S) was calculated from the vapor pressure for the mean annual temperature and the relative humidity. (V. P. × [100—relative humidity]).

Thornthwaite (5) has devised a new classification of climates, based on precipitation effectiveness and temperature efficiency. The sum of $\frac{P}{E}$ and $\frac{T}{H}$ ratios for each month gives a $\frac{P}{E}$ index and a $\frac{T}{E}$ index for the year. The value E is calculated from the temperature, by use of an equation derived from values for stations with evaporation data.

Based on any of these considerations, Ohio is in an intermediate climatic area, but not far from the borders of the cool humid area to the north, the warm humid area on the south and the prairie area on the west. Although there is not much variation in climate within the bounds of the state, it would not take much change in either temperatures or rainfall to shift the area into one of the other climatic belts. In fact, the vegetation shows relics of all three of the neighboring climatic belts. Some of the climatic relationships are summarized in Table I.

The vegetation factor will be discussed in detail by Dr. Transeau. Suffice to say here that most of our soils have developed under a dense mixed hardwood forest. The possible effects of past changes in climate and in vegation have not been evaluated.

In addition to the factors of climate, vegetation, drainage and relief in soil development, age is an important factor. Time alone is not the only factor, the rate of change must be considered. For the mature soil to develop the material must stay in place for a long period of time. But there are different degrees of maturity. For example, the soils derived from the Illinoian drift have leached to a depth of 8 to 10 feet, those from Lake Wisconsin drift to only 2 or 3 feet—this being a result of the difference in age. The drift of both areas is highly calcareous.

As a result of the action of these various forces on the soil material, profound changes have taken place, varying in intensity from the surface downward. The soil forming processes include the following:

1. The decomposition of the minerals of the soil material.
2. The accumulation of organic matter on the surface and within the upper soil horizons.
3. The leaching of soluble products of decomposition of both mineral and organic matter.
4. The translocation downward of soil material from some layers and the deposition in others.
5. The formation of new compounds by decomposition and by recombination.
6. The development of structure with the production of aggregates that break along rather definite lines.

TABLE I.

PRECIPITATION EFFICIENCY

	Ohio Gray-brown Podzolic Soils	Podzol Soils	Red and Yellow Soils	Prairie Soils
$\frac{P}{E}$ (Transeau)	80–100	130–150	100–130	60– 80
$\frac{R}{T}$ (Lang)	80– 90	110	65– 80	70– 90
N-S-Q (Meyer)	300–350	500–800	300–450	300–400
$\frac{P}{E}$ (Thornthwaite)	64–128	64–128	64–128	48– 64
$\frac{T}{E}$ (Thornthwaite)	48– 64	32– 48	64–128	32–128
Mean Annual Temp.	54°F. (12°C.)	40°F. (4°C.)	68°F. (20°C.)	42°F.–56°F.

In the investigation of soils their character, or morphology, is carefully studied in the field. Representative samples of the horizons are subjected to examination in the laboratory, their physical and chemical composition are studied. However, a chemical analysis must be supplemented by mineralogical studies to give an idea of the mineral composition of the material. A study of the mineral composition of the coarser fractions of the soil gives an idea of the unweathered, resistant minerals and is an aid in tracing the origin back to the parent material. Only within the last few years has it been possible to identify the products of weathering—the clay minerals (6). The methods for identification include the X-ray diffraction method, dehydration studies and others, along with chemical analysis of the clay minerals.

Studies have revealed the presence of a number of hydrated aluminous silicates. Only in tropical or subtropical regions does the silica-aluminium ratio approach the 2 to 1 value required for kaolinite—$Al_2O_3 . 2SiO_2 . 2H_2O$—the commonly suggested product of weathering of feldspars. Assuming a ratio in the unweathered mineral of 6 to 1 as in orthoclase—$K_2O . Al_2O_3 . 6SiO_2$—the common clay minerals in soils of humid temperate regions have a ratio of 3 or 5 to 1. These minerals have been identified as montmorillonite, beidellite, etc. They have high base exchange capacity, high water absorption capacity and high plasticity. Another group of minerals, variously called illite, glimmerton, X-mineral and hydrous mica, are somewhat similar to muscovite in composition, but contains less potash and more water by hydration along with silica and alumina.

In contrast to these are the clay minerals in lateritic soils of the subtropics in which the silica-alumina ratio is approximately 2 to 1 as in kaolinite. However, the common mineral has been identified as halloysite, which contains more water of hydration than kaolinite. They are characterized by low base exchange capacity and low plasticity. In laterite—a red soil of the tropics—the common mineral is a hydrated aluminum oxide. This whole field of the mineral character of clay minerals is a new one, the future should yield an abundance of important information.

Given sufficient time the net result of all of this is the development of a soil profile with layers or horizons with definite and distinctive characteristics. In case these processes go on unimpeded, either by erosion as on steep land, or by a high water table, as on very gently sloping or level land, the nature of the soil developed will be primarily an expression of the effects of climate and vegetation—external forces in soil development. These soils can be called mature soils or normal soils. Such soils, owing their characteristics primarily to climatic and biological (chiefly vegetation) agencies, occur in zones or areas corresponding closely with climatic and vegetation zones and hence, have been called *zonal* soils.

These are the naturally well drained soils of the state (7)—some are derived from materials high in lime, as in western Ohio, some from materials low in lime and some from noncalcareous materials as in northeastern Ohio. These are the best wheat soils of the State.

These features are characteristic of the great soil group, the gray-brown podzolic soils, and are distinct from the podzol soils to the north, the red and yellow soils of the south and the dark-colored prairie soils to the west. This soil zone extends from the prairie in Indiana and Illinois to the Atlantic seaboard. Throughout the whole area the main characteristics of the normal mature soil are essentially alike.

In association with the zonal (normal or mature soil) are soils which because of poor drainage, or steep topography have not developed the normal mature profile. These are called *intrazonal* soils, in that their chief characteristics are the result of some internal factor or condition. In one case adequate artificial drainage may be a first essential for their utilization; in the other case the erosion hazard may be a limiting factor.

In addition these soils are those which for one reason or another, show little or no profile development. Recent alluvial deposits are a good example. These are called *azonal* soils.

The typical zonal soil of Ohio, irrespective of soil material, has the following features:

1. A thin layer of leaf litter.
2. A dark grayish-brown layer, 2—3 inches thick.
3. A grayish-brown to brown soil.
4. A light yellowish-brown subsurface about the same in texture as the surface soil.
5. A yellowish-brown upper subsoil somewhat heavier than the surface soil, 10 to 15 inches thick, with a definite blocky structure.
6. The more or less unweathered soil material.

In association with the light-colored well-drained soils, and derived from similar soil material, are the poorly drained intrazonal soils. Those that are dark in color, with adequate artificial drainage prove to be the best corn soils of the state. The poorly drained light-colored soils, the gray soils, are characterized by a tight impervious subsoil. They are the most difficult to drain, the most acid, and are the lowest in productivity, of any of the soils in the association. To these gray poorly drained soils the group name of *planosols* has been given.

At the other extreme are the soils developed on steep slopes where geological erosion has kept pace with soil development. Here there is only a thin layer of soil over partially decomposed rock. Under such conditions the erosion hazard is the limiting factor in land use. Such soils are called *lithosols*.

Soils derived from similar soil materials, whose chief differences are the result of differences in topography and drainage are grouped in a *soil catena*, and the name of the best drained soil in the group is used for the name of the catena: For example, the Miami catena includes the soils derived from glacial limestone drift. The soils of a catena may be closely associated together in an area, on a farm, and even in one field.

As a result of the interaction of the forces of soil development, a variety of soils have been produced. Each has its distinctive characteristics. In its utilization in the production of crops useful to man each soil has its particular adaptations, its distinctive problems in soil conservation. Although the soils of the region naturally are of only moderate natural fertility, they are very responsive to good management and under the favorable climate form the basis of a stable agriculture.

On the level areas drainage is a problem. In the lake plain areas of northwestern Ohio, the heavy clay soils show a marked deterioration in structure with a resulting lowering in crop yields. In northeastern Ohio, the problem of soil acidity is uppermost. Better drainage on the smoother areas, erosion control on the rolling areas near the glacial border, are essential in an adequate land use program.

In southeastern Ohio the problem of erosion control is dominant in land use planning. Many steeply sloping areas, not adapted for rotation crops, can best be utilized for permanent pasture or for forests. The deeply leached soils of southwestern Ohio present a multiplicity of problems. The extensive gray soils on the broad flats are difficult to drain, are highly acid, and are very low in productivity.

Thus each area with its distinctive soil association presents its special problem in soil utilization. Situated as we are on the eastern edge of the corn belt, and at the western border of the Appalachian Plateau, we have a variety of problems in soil conservation.

LITERATURE CITED

(1) Soils and Men, U. S. D. A. Yearbook of Agriculture, pp. 948–1001. 1938.

(2) **Transeau, E. N.** Forest Centers in Eastern United States. Amer. Nat., 39: 875–889, 1905.

(3) **Lang, R.** Investigation of an exact classification of the soil from the climatic and geological point of view. Inter. Mitt. fur Bodenkunde, 5: 312–346. 1915.

(4) **Meyer, A.** Concerning several relationships between climate and soil in Europe. Chemie der Erde, 2: 209–347. 1926.

(5) **Thornthwaite, C. W.** Climates of North America. Geog. Review, 21: 633–655. 1931.

(6) **Alexander, L. T., Hendricks, S. B.,** and **Nelson, R. A.** Minerals present in soil colloids. II. Estimation in some representative soils. Soil Science, 48: 273–279. 1939.

(7) **Conrey, G. W.,** and **Burrage, E. M.** A key to the soils of Ohio. Ohio Agricultural Experiment Station Spec. Circ. No. 44. Revised Edition. 1938.

Solids

Modern Theory of Solids by Frederick Seitz is the title of a new volume in the International Series in Physics. The work is an attempt by the author to present the subject matter so that students in physical sciences may obtain a certain knowledge of this branch of physics and for experimental men in the pure and applied fields of physics and chemistry, but at the same time also for men engaged in theoretical physics. For the benefit of the former groups certain tracts are marked with an asterisk to indicate that these are essentially mathematical in character and may be read only for their qualitative content. The theoretical man will often want to refer to and study these sections with some care.

The first four chapters are essentially introductory in character and present the subject matter in a classical manner. In Chapter Five the quantum theory is first introduced, part A being devoted to the postulates of the theory and part B to the interaction between matter and radiation. The next two chapters are in reality extensions of the theory to the many-bodied problem and application to problems in molecular binding. Succeeding chapters take up such topics as cohesive energy, work functions, electronic structure of metals, ionic crystals, valence crystals, semi-conductors and molecular crystals; the theory of conduction in solids and the magnetic and optical properties of solids.

In the opinion of the reviewer the volume is a valuable asset to anyone engaged in research in physical science. It is readable but at the same time a rigorous treatment of the subject is available to the reader who desires to look beneath the surface. It is well-illustrated throughout with clear and helpful diagrams. Modern Theory of Solids by Seitz is a valuable addition to the Internation Series in Physics.

—*H. H. Neilsen.*

Modern Theory of Solids, by Frederick Seitz. xv+698 pp. New York, The McGraw-Hill Book Co., 1940. $7.00.

PREHISTORIC FACTORS IN THE DEVELOPMENT OF THE VEGETATION OF OHIO

EDGAR NELSON TRANSEAU,
Ohio State University

During the half century that has elapsed since the organization of the Ohio Academy of Science numerous papers have been presented at its meetings in which the distribution of the flora and plant communities of Ohio was discussed. Most of these papers described local areas, county surveys, or the character of the successions in various parts of the state. Usually some attempt was made to relate the findings to climatic and soil factors. Others have discussed the relations of Ohio vegetation to that of surrounding states and have attempted to describe its origin.

During the past twenty-five years, the vegetation of numerous counties has been studied in some detail and checked with the survey records of pioneer days. At the same time our knowledge of the native flora of Ohio has been greatly increased through the finding of many unrecorded species and by the discovery of many new localities in which previously recorded species are living.

Meanwhile, additional details of preglacial, glacial, and postglacial changes in drainage in physiography and in soils have been brought to light by our geologists and pedologists.

The early authors who discussed the distribution of plants in Ohio were content to speak of the plants from the north and the south, or the east and the west. The publication of the glacial geologists, however, furnished a more intelligent basis for relating our present flora and vegetation to the climatic fluctuations of the past, especially the changes that resulted in the melting of the last ice sheet. This was followed by the northward migration of plants from south of the glacial boundary across the state to Canada. Certain authors talked of successive waves of tundra, boreal forest, and deciduous forest species moving northward into the lands uncovered by the ice. These generalizations definitely recognized the importance of (1) the historical factors as well as the complex of present day climatic and soil factors; and (2) distinguished clearly between the successions that are occurring under present conditions, and the successive vegetation types that may have occupied the state as a result of the larger prehistoric climatic shifts and physiographic changes (1, 2).

One of the members of this Academy also inaugurated in this country the now widespread study of peat deposits from the point of view of the kinds of pollen preserved in successive layers from the beginning of peat formation in ponds or lakes to the present time. These studies have given us by far the most definite records of the predominant vegetation types during prehistoric times (4). Most of the published records present the successive pollen frequencies of post-Wisconsin time, but it is not unlikely that in the course of time interglacial, and perhaps even preglacial peat deposits may yield similar information concerning earlier migrations of vegetation during the Pleistocene and before. Fragments of this nature have been found, but apparently none covering very long periods.

From the pollen studies it now seems clear that during the post-Wisconsin epoch in central Ohio, forests of Jack pine, white spruce, and black spruce followed closely the retreating edge of the ice and that there was no distinct zone of tundra along the ice margin. White and black spruce forests were the predominant types for a very long time, perhaps the first half of post-Wisconsin time. This forest was at length invaded by northern oaks and pines. About the beginning of the last third of postglacial time, white pine with hemlock became the predominant species on the Ohio upland. Only during the last several thousand years have the oaks, hickories, and other deciduous species been dominant, following a rapid disappearance of the white pine and hemlock. The dominance of beech and maple over the greater portion of the state is the latest change in the prevailing vegetation.

At some time during the latter part of this record there was a long dry period that led to the invasion of Ohio by prairie species and communities similar to those of Illinois and Iowa. Whether it coincided with the dominance of white pine and hemlock or whether it resulted in the decline of this forest type remains to be determined (7).

The first effects of the Xeric period must have been the death by drought of trees in the swamp forests and the moderately moist habitats. This was followed by increased frequency and intensity of natural forest fires which opened up large areas of land to the prairie plant invaders. The prolonged droughts of the Xeric period also resulted in the elimination from the region of the prairie peninsula of many forest species which survived both north and south of this region.

The occurrence of many rare or out-of-range species on the peninsulas, lake shores, and islands of the upper Great Lakes is probably more related to their elimination elsewhere, especially from the area of the prairie peninsula by prolonged droughts in late post-Wisconsin time, than to the assumption that the areas in which they now occur were unglaciated. Most of these areas were not only glaciated, but were submerged in proglacial lakes for centuries following the slow retreat of the edge of the ice sheets.

At what time the upland hard pines and their associated shrubs and herbs came into Ohio from the Alleghany and Cumberland plateaus is unknown. Likewise, the time of the migration of sweet gum, pecan, pumpkin ash, and other species from the bottom lands of the Mississippi Embayment is not clear. It seems possible, however, that there were scattered upland pines here during the entire Pleistocene and that some of the Embayment species may have arrived in pre-Wisconsin time.

There are, however, some other isolated plant colonies in Ohio that seem to be definitely survivors of pre-Pleistocene time. They contain typically Appalachian species that may have come into the state by way of the pre-glacial Teays valley, or may at one time have been generally distributed throughout the Alleghany and Cumberland plateaus. At the present time, they are far separated from their next nearest stations in West Virginia and Kentucky and it is highly improbable that their occurrence here is accidental. As a rule they are hilltop and cove species.

We have called attention previously to the pre-glacial Teays valley which had its headwaters in West Virginia, Virginia, and western North Carolina. This great river system, together with other smaller rivers north and west, must be regarded not only as carriers of seeds and propagules to Ohio, but as agencies of erosion which carved a vast network of valleys and canyons across the mountains and plateaus. These valleys afforded not only a continuous series of bottom land habitats, but also parallel lines of steep slopes, cliffs, and ridge tops where the migration of upland species might readily proceed.

One of the striking facts about the species the distribution of which in Ohio may be directly or indirectly related to these river valleys and ridges is their absence at the lowest altitudes of the state. Among such isolated species are *Rhododendron maximum*, *Magnolia tripetala*, *Magnolia macrophylla*, *Styrax grandifolia*, *Pachystima canbyi*, *Calycanthus nanus*, *Azalea lutea*, *Oxydendrum arboreum*, *Chionanthus virginica*, *Polypodium polypodioides* and *Lygodium palmatum*.[1] The stations of these plants are singularly remote from other stations in the plateaus. Most isolated species are those which are characteristic of unoccupied or pioneer habitats, but most of these species are distinctly examples of undergrowth in well established forest communities.

Moreover, there are certain localities in the state such as Liberty township in Jackson County, and the Blackhand sandstone area of Hocking County (3) which have remarkable isolated assemblages of species growing in habitats that apparently are not unlike those in many other parts of unglaciated Ohio, but in which comparable assemblages are lacking. I use the term assemblages because the plants included are strikingly heterogeneous, as to habitat, taxonomic relations, and community affiliations. They range all the way from species of pioneer communities to those of climax associations and various ones are usually considered to be characteristic of boreal, hemlock-hardwood, deciduous, or prairie associations. Morevoer, the disjuncts include flowering plants, conifers, ferns, mosses, lichens, and algae. Both areas have a marked diversity of edaphic and microclimatic situations, but scarcely more so than various other areas in Southeastern Ohio. Both are areas having elevations considerably above the 900 foot level.

Assuming that our data are relatively complete, it is at least possible that the absence of these species in ravines, coves, and rock ledges remote from the higher uplands is a consequence of geological events connected with the earliest invasion of Central Ohio by an ice sheet, long antedating the Illinoian epoch. The northwestward flowing Teays river was dammed when the ice pushed across its valley and there must have resulted a rising flood that became a proglacial lake of vast proportions. Its southern and southwestern boundaries at the time of its maximum depth are not clear, but the lake probably extended as far west as the Licking valley of Kentucky, as far east as the present

---

[1] Across the Ohio river from Lawrence and Scioto counties are isolated stations of *Pinus pungens* and *Quercus ilicifolia*.

Kanawha in West Virginia, as far north as Northern Ross and Athens Counties, and 40 to 50 miles south of the present day Ohio River.

Within the boundaries of this lake in Kentucky, which rose to levels above 900 feet, the geologists have discovered nearly a score of large glacial boulders. The composition of the rocks is reported to be unlike that of any rocks of the Ohio drainage basin, but similar to certain rocks of Eastern Ontario. These boulders must have been carried to their present location far beyond the Illinoian and Wisconsin terminal moraines, either directly in the ice of an earlier glacial invasion of Kentucky, or indirectly by icebergs floating on a deep proglacial lake. The evidence now available points to the latter alternative. Either alternative, however, would imply the formation of a large lake in southeastern Ohio, adjacent West Virginia, and Kentucky.

The duration of this lake is of the greatest significance as a destroyer of vegetation, since it existed a length of time sufficient for one to two hundred feet of silt and sand to accumulate. This silt eventually filled all the valleys to near the 900 foot level and obliterated the underlying topography. This conclusion is based on the fact that when an outlet was opened over a divide somewhere and the lake was gradually drained, many of the renewed streams did not return to their former valleys, but found new outlets to the Ohio River which was pieced together from various preglacial streams during the draining of this lake (5, 6).

A proglacial lake in this location must have been subject to great fluctuations in water level. To the north were the ice masses subject to rapid or slow melting, depending upon temperature and rainfall conditions. To the east and south the vast drainage area of the plateaus was subject to flooding through sudden melting of deep snows and heavy rainfall. The flood in the Ohio basin in the winter of 1937 caused the river to rise 60 to 80 feet in this same region. When the weather conditions at the edge of an ice sheet are compared with those of the present climate, and the fact that the outlets for the water were far more restricted than at the present time, it is not impossible to account for the large Kentucky boulder that was deposited at the 1000 foot level.

In speaking of the indirect effects of the ponding and reversal of drainage of this ancient lake, I have in mind the profound effect it had on the soils of the filled valleys, and the valley terraces. Thus, there was not only the destruction of all vegetation in the areas submerged, but a complete change in the soils to which plants that may have survived on islands and peninsulas might have subsequently migrated. When the stream flowed northwestward the soils of this area were derived from shales and sandstones of the plateaus. When the streams of the plateaus were ponded the streams from the glaciers carried calcium and magnesium carbonates from the limestone of central and northern Ohio. Moreover, it was not until the silts had been eroded and removed by subsequent streams that many of these habitats were uncovered and developed their present characteristics. Thus, today there are many localities in southern Ohio where, for example, rhododendron might be expected to occur, but in which it is absent.

It may at first thought seem difficult to believe that some of the rare plants in the Jackson and Hocking regions have been there during the entire Pleistocene. Nevertheless, I am suggesting this possibility, and also that this earliest great proglacial lake[2] was one of the factors that contributed to the isolation of certain species in these remote localities. There may have been other and later factors that contributed to the extermination of these plants on other areas above the 900 foot level. One of my associates will in the near future publish further details concerning the possible boundaries of the lake and complete lists of the species in these two veritable living museum areas.

The impression is now growing that the historical factors are far more important in explaining the limits of associations and communities than we have ever imagined, and that vegetation patterns of the past remain for very long periods after the factors that initiated them have disappeared. In the list of papers below are other hypotheses concerning historic and prehistoric factors that may have influenced the present distribution of plants of Ohio. Also, there are other guesses as to how long some of the unusual habitats have been undisturbed, and when certain isolated groups of species migrated into Ohio. As more details of Pleistocene geography are discovered certain of these suggested explanations will be rendered either more plausible, more improbable, or definitely impossible and we shall be nearer a satisfactory history of Ohio vegetation.

REFERENCES

(1) **Braun, E. L.** Glacial and Post-Glacial Migrations Indicated by Relic Colonies of Southern Ohio. Ecology, 9: 284–302. 1928.
(2) **Braun, E. L.** A History of Ohio's Vegetation. Ohio Jour. Sci., 34: 247–257. 1934.
(3) **Griggs, R. F.** Observations on the Geographical Composition of the Sugar Grove Flora. Bull. Torrey Bot. Club, 40: 487–499. 1913.
(4) **Sears, P. B.** Glacial and Post-Glacial Vegetation. Bot. Rev., 1:37–51. 1935.
(5) **Stout, W., and G. F. Lamb.** Physiographic Features of Southeastern Ohio. Ohio Jour. Sci., 38: 49–83. 1938.
(6) **Tight, W. G.** Drainage Modifications in Southeastern Ohio. U. S. Geol. Surv. Prof. Paper 13. 1903.
(7) **Transeau, E. N.** The Prairie Peninsula. Ecology, 16: 423–437. 1935.

---

[2] This lake might very properly be called "Tight Lake" in honor of the geologist who first mapped the drainage modifications in southeastern Ohio.

More About Science in Relation to Society

The title of this book designates a topic almost as old as science itself and it has long been a favorite theme for lecturers and authors, particularly during periods of considerable social and political change. During our present turmoil, many individuals are expressing judgments on science (and almost every other subject also) and there is little agreement amongst them. We have before us a book in which the author offers information, almost entirely historical, to prepare individuals for doing their own thinking about the relationships between science and society; it is a presentation of data rather than of theory and for its purpose is worthy of earnest consideration.—*Carl Venard.*

The Social Relations of Science, by J. G. Crowther. xxxii+665 pages. New York, The Macmillan Co., 1941. $3.50.

THE AERIAL TRAVERSE

AN APPLICATION OF AERIAL PHOTOGRAPHY TO GEOGRAPHIC STUDIES

JOHN L. RICH,
University of Cincinnati

Because of the comprehensive view of the landscape which it affords, the airplane makes possible a new mode of attack on geographical problems, especially on those which deal with any aspects of the distribution and special interrelations of geographic features. The observer in a plane is not limited as is the ground observer who depends on natural elevations for his outlook points. Whether the topography is flat or mountainous, altitudes may be chosen such that considerable areas can be included in a single view, and the point of view can be changed at will—a great advantage. The pattern of land utilization, the distribution of cultivated land with respect to topography, control of communication routes by topography, distribution of vegetation with respect to topography or to geological features, and numerous other aspects of geographical problems may be seen and studied in their mutual relations better from an airplane than in any other way. Photography preserves a permanent record of such information that can later be studied at leisure, and can be supplemented as necessary by work on the ground, provided the location of each of the pictures is definitely known.

The extensive network of airlines in the United States makes it possible for the geographer to select routes covering almost any of the principal types of geographic environment, so that in order to make extensive use of this new method of geographic study and recording it is generally not necessary to charter a special plane, although it may be desirable for special studies of particular areas.

LOCATION

As already suggested, for rigorous scientific work it is necessary that the exact, or nearly exact, location of each picture be known, so that the features which it shows can be properly placed on a map and so that the district may be visited later on the ground if necessary for proper interpretation of features shown on the photographs.

During flight, the procedure necessary for locating the pictures is to record the time when each picture is taken to the nearest practical division of a minute—generally to the nearest quarter minute—and also to record the time of the passage of the plane over or past objects such as towns, railroads, or rivers, which can be recognized on the small-scale map which the observer carries with him in the plane.

Such a map should be on a scale of about eight to twelve miles per inch. The writer has found the most satisfactory maps for this purpose to be the State maps on those scales, which are available in almost any bookstore. Those maps commonly show cities and towns, railroads, and drainage—the features most readily recognized by an observer in a plane. Highways are not satisfactory because in most regions they are too numerous and are not readily identified. Consequently, automobile highway maps of the states are not satisfactory.

The approximate line of flight along a regular air route is, of course, known in advance. The observer marks in pencil a straight line along the proposed route which is helpful in enabling him to find quickly on the map objects over which he passes. It is also useful to prepare in advance on a 3 x 5 card a scale in minutes corresponding to the scale of the map used. For example, if the plane is flying at three miles per minute, which is perhaps a little faster than the ordinary cruising speed of the modern transports, the scale would show distances according to the scale of the map traversed in 1, 2, 3, 4, 5, and so forth, minutes. If one passes over clouds, or for any other reason loses contact with known ground features long enough to become doubtful of his location, the approximate location can then be determined quickly by applying to the map such a scale and measuring along the flight line from the last identified point.

The observer carries in the plane, in addition to the map and the scale just described, a convenient notebook in which to record the film roll number of each picture, a brief description sufficient to identify the subject, and the time the picture is taken. If pictures are taken in rapid succession, it may be possible to record only the time, but the picture itself will generally supply the needed information later.

With a little practice, the observer, knowing his approximate height (which can always be obtained from the pilot) learns to judge closely enough for location purposes the distance to objects on the ground, such as towns, bends in rivers, etc., so that it is not necessary to pass directly over them in order to use them for location.

PHOTOGRAPHY

In modern planes it is necessary that all photographs be taken through the plane window. The window, being made of laminated, shatter-proof glass, must of course introduce some distortion and blurring of the image, but so little that it is scarcely recognizable on the photographs. Disturbed air from the exhaust of the motor, which is sometimes in the line of vision for part of the photograph, causes more serious blurring, but even this is seldom recognizable. Even dirt on the windows, unless excessive, does not seem to cause difficulty. Satisfactory pictures have been obtained through the windows of a flying boat noticeably clouded with evaporated ocean spray. In photographing through a plane window, however, it is necessary that the camera be held as close to the glass as practicable without touching. To avoid the effects of vibration, neither the camera nor the operator's hands should be in rigid contact with the plane. If the camera is held too far from the glass, reflections of objects in the plane may cause trouble.

The Camera:

Any good camera may be used, but there are many advantages in using one of the "miniature" type cameras using 35 mm. film. One of the great advantages is that such cameras can be operated very quickly and easily, so that pictures may be taken in rapid succession, and another is that the number of the picture on the roll is shown on the exposure counter, so that each picture can be referred to by number. A third important advantage is that about 35 pictures may be taken before it is necessary to change rolls. With such a camera, enlargements to 5 x 7 inches have been secured that are microscopic in detail, that is, objects invisible to the naked eye on the enlargement can be seen with a hand lens.

Film:

To permit satisfactory enlargements, a fine-grained film is desirable. It is essential that the film have an emulsion yielding relatively high contrast. Ultra rapid film should be avoided because it tends to be flat and lacking in contrast, and to have coarse grain. A rapid emulsion speed is not necessary or desirable. Among Eastman films, Background-X (a commercial film prepared for the motion picture industry and not available in most photographic stores) has been found highly satisfactory. It is fine-grained, and has relatively strong contrast. Eastman Panatomic-X is satisfactory, but is not quite so contrasty as the Background-X. Dupont "Quarter speed" film has been used with success, but has perhaps a little too much contrast. Kodachrome can be used successfully, but color values may be slightly, though not seriously, distorted by the greenish tinge of the plane window.

Exposure:

The exposure should be such as will permit full development so as to obtain maximum contrast. The exposure will, of course, depend on the film used, and on light conditions. On an ordinary sunny day in the United States, using Background-X or Panatomic-X film and a light yellow (K-2) filter, a speed of f-6.3 and 1-100 second is perhaps average. The proper timing can best be obtained by testing the film from a high point of ground before the flight, recording light meter readings, making several exposures both longer and shorter than those called for by the light meter, checking the results after development, and choosing the factor which gives best results.

Unless the plane is flying close to the ground, its motion relative to the ground does not necessitate a rapid shutter speed. At heights of 2,000 feet or more, speeds as low as 1/40 or 1/30 second will give satisfactory results, although of course, if light conditions permit, shorter exposures are desirable. The principal cause of blurring is not the plane's speed relative to the ground, but motion of the plane if the air is rough. In smooth air, no trouble is encountered, but in rough air short exposures are necessary and even then it is difficult to avoid blurring. With a camera having a focal plane shutter, exposures less than 1/100 second can be used, but they give uneven lighting across the film. Apparently there is an inertia lag in the shutter which results in one side of the film being exposed more than the other. A similar uneven exposure results when a picture is taken with the sun approximately either in front or behind the plane, because on the half of the picture toward the sun the haze or dust particles do not reflect light into the lens and consequently do not affect the illumination, but on the side away from the sun such reflection noticeably increases the light intensity. This effect, of course, depends on atmospheric haze, and is at a minimum on exceptionally clear days. It can be compensated by "dodging" during enlargement. On account of atmospheric haze, a filter is necessary for all pictures except those taken steeply down at relatively low altitudes. The writer has used the light yellow K-2 filter, but is not certain that this gives the best results under hazy conditions.

Development:

Development should be such as to give strong contrast and at the same time as fine grain as possible. Compared with ground photography, there should be a tendency toward under exposure and over development for the sake of contrast. The Eastman D-76 formula has given best results.

Stereoscopic pictures:

With a miniature camera permitting exposures in rapid succession, it is entirely practicable and for some types of work very advantageous to take oblique steresocopic pictures. The essential requirement is only that the two pictures composing the steresocopic pair be taken in as rapid succession as possible with the camera pointed at the same objects. For any geographic work in which it may be desirable to study relief features, stereoscopic pictures are especially useful.

LOCATING THE PICTURES ON THE MAP AFTER FLIGHT

Having obtained during flight the time when each picture was taken and the time when the plane passed over known objects or control points at intervals of 15 to 30 minutes, the procedure for locating the pictures on the map is to draw the flight lines as straight lines between control points on a base map of suitable scale, and then to obtain the location of each picture along these lines in porportion to time and distance. A slide-rule is extremely useful for this purpose. This procedure assumes uniform speed and straight line flight between control points. In a region for which detailed topographic maps are not available, locations so made must be accepted as final unless the observer at the time has made notes as to deviations from straight-line flight which may have occurred, or unless features shown on the pictures permit more definite location. Deviations from a straight course are rare, however, in ordinary scheduled flight, and locations so made will ordinarily be correct within a mile or two. Even in the rather featureless sand hills of western Oklahoma, the sites of pictures so located have been found without difficulty on the ground.

If a detailed topographic map is available, the location of the pictures can then be determined exactly because the locations on the smaller-scale map, made as above described, will be close enough so that on the detailed topographic map objects shown in the pictures can readily be found. It is then possible to make any necessary corrections in the line of flight and in the location of the pictures along it.

ADVANTAGES OF THE AERIAL TRAVERSE IN GEOGRAPHIC STUDY

By the methods above described it is possible by flight over a region on a clear day to make a photographic record of geographic features along the route with sufficient detail so that all significant changes in topography or culture may be recorded, as well as typical examples of each. The result is an essentially complete photographic record in traverse form. Such a record seems to have great possibilities for usefulness because the photographs tell the story much more vividly than it can be told in words.

EXAMPLES OF THE METHOD AS APPLIED TO OHIO AND THE PANHANDLE REGION OF TEXAS

The accompanying pictures are introduced to illustrate the types of geographical information obtainable by the methods described. The first eight pictures illustrate typical aspects of Ohio geography.

Figure 1 may be taken as representative of the Wisconsin glacial till plain. The ground is almost perfectly flat, drainage is as yet unorganized, and the soil shows the characteristic mottling of light and dark, in which the darker areas represent the black soil on the lower ground. Such glacial plains constitute the rich agricultural land of much of Ohio, Indiana, Illinois, Wisconsin, and Iowa. Interesting details in this picture are a trunk highway crossing the center of the picture; a field of wheat in shock lying beyond the highway at the left; and a field of uncut wheat that may be recognized on the near side of the highway at the right by the lines of oval dark spots which represent the positions where corn shocks stood the preceding autumn when the wheat was planted.

Figure 2 shows a typical aspect of the Illinoian glacial till plain about two miles northeast of Georgetown, Brown County, which appears at the upper right of the picture. Clearly this plain has been exposed to erosion much longer than the Wisconsin plain of Fig. 1 because stream drainage has here developed to an early mature stage. A well organized dendritic drainage system may be seen in the lower half of the picture, but in the upper half the original flatness of the till plain has not yet been destroyed. In the lower half of the picture the ravages of soil erosion can be clearly recognized in the white bands bordering each of the minor tributary valleys.

Figure 3 illustrates a typical floodplain—that of Scioto River immediately north of Piketon, Pike County (between Piketon and Waverly). The river, crossed by a bridge, appears in the foreground. In the upper right half of the picture is a large meander which has recently been cut off, and on either side of the floodplain the wooded hills may be recognized. The picture is interesting primarily because it shows one of the commonest features of floodplains as they appear from the air, namely the "tracks," represented by curved bands of light soil, of ancient meanders showing successive periods of their growth and abandonment.

Figure 4 showing the floodplain of Scioto River immediately northwest of Portsmouth, Ohio, represents an even more striking development of floodplain features. Scioto River crosses the lower left and the Ohio the upper left corner of the picture. Many abandoned meanders can be seen, some of them still containing oxbow lakes, as at the upper left, and others made visible only by variations in the color of the soil. Some of these ancient meanders and former ox-bow lakes, though plainly visible, are so nearly obliterated topographically that, as shown near the center of the picture, the farmers plough across them without deviation. The border of the floodplain is followed by a highway, beyond which are the wooded hills. A suburb of Portsmouth (Bertha) appears at the right center.

Figure 5 shows an interesting development of orcharding on the floodplain and low terrace on the Ohio side of the Ohio River, about seven miles east-northeast of Huntington, West Virginia. The bluffs bordering the terrace appear at the lower right. Extensive orchards may be readily recognized by their distinctive pattern. Soil differences resulting from meander growth of the Ohio may be detected by color changes and seem to have been reflected in property ownership, as indicated by the pattern of the fields.

Figure 6 portrays a typical example of the unglaciated portion of eastern Ohio. Erosion of the region, whose relief is about 300 feet, has passed somewhat beyond maturity. Cleared farmlands are divided almost equally between upland divides and valley bottoms. About one-third of the area is wooded—mainly on the steeper valley sides.

Figure 7. In the maturely dissected, unglaciated Alleghany plateau, soil erosion is serious. One of the most effective means of combatting erosion is "strip cropping," of which a particularly fine example is here shown. Strips of ground contouring the hills are planted with different crops in such a way that a crop, such as corn, that promotes erosion alternates with another like alfalfa, that holds the soil in place.

In the center of the picture the corn shocks on three of the strips are readily recognized. The darker strips are probably grass or alfalfa, and the lighter probably wheat.

Strip cropping is not yet extensively used in the plateau, but a few fields so cultivated may be seen in almost every neighborhood (see Fig. 6 near center) and soil conservation agencies are urging its wider adoption.

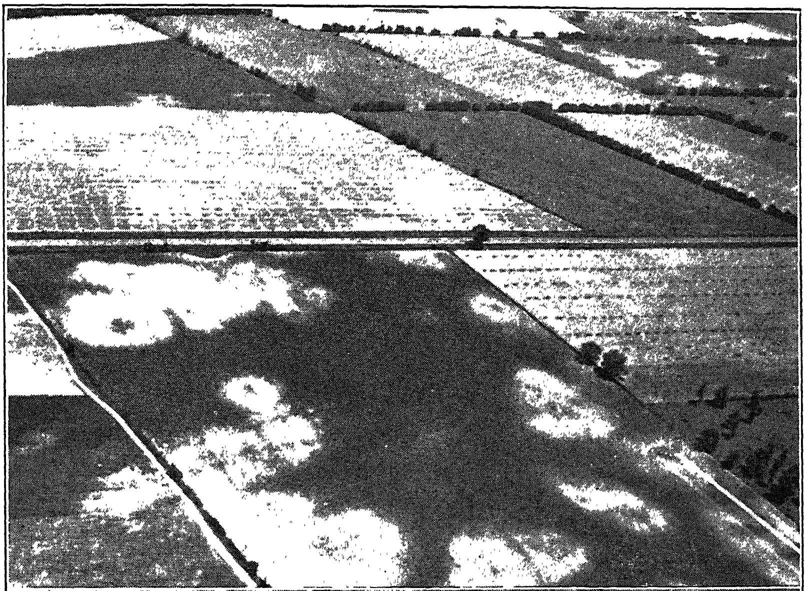
Figure 8. A type of mining that is extensively developed in eastern Ohio—the strip mining of coal—is strikingly revealed from the air.

In strip mining, which requires that the coal bed lie close to the surface over considerable areas, the overburden of soil or rock is removed by power shovels which strip it from above the coal and swing it to one side where it is piled in great wind-rows, such as are shown on the photograph. In this area an overburden of nearly 50 feet has been removed to recover a bed of coal 30 inches thick. The aftermath of strip mining, as is well illustrated on the picture, is almost complete devastation of the area mined. Rehabilitation of the land ruined by strip mining is one of the problems confronting the State. For agriculture, the land is probably permanently ruined, but certain types of forestry offer possibilities for rehabilitation.

By way of contrast to Ohio, two photographs are introduced illustrating a totally different geographical environment—the Panhandle region of Texas.

Figure 9 illustrates the sand hills which border the Canadian River, a short distance north of the village of Clear Creek, Hemphill County, Texas. A railroad crossing the lower right corner of the picture serves as scale. Sand has been blown for several miles to the east, from the usually nearly dry bed of Canadian River and piled into low, irregular dunes, such as those shown on the photograph. Most of this sand appears now to be stationary, as is evidenced by its partial vegetation cover, and only occasionally do active "blow-outs" testify to present movement of the sand. This condition suggests a more arid climate at the time these sand hills were formed.

Figure 10, taken late in the afternoon along Red Deer Creek, about five miles northwest of Miami, Roberts County, Texas, is a beautiful study of erosion working headward from one of the larger streams into the grassy plains of the Texas Panhandle. Scale is indicated by a railroad which crosses the picture beyond the sandy bed of the"river."



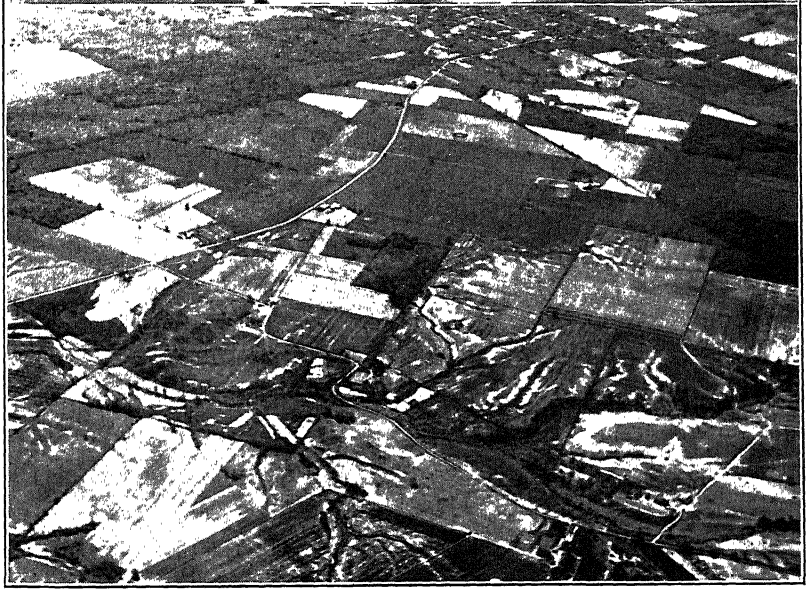
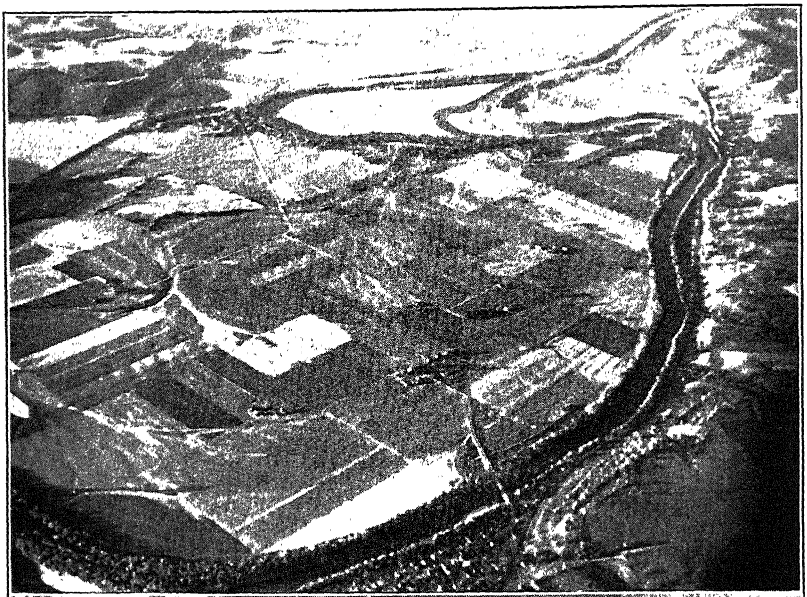


Fig. 1 (upper). Till plain of the Wisconsin glaciation, with characteristic soil mottling. Looking north. Center of picture 39° 47.5′ N., 83° 13.6′ W., 12½ miles west of Columbus, Ohio.

Fig. 2 (lower). Till plain of Illinoian glaciation northeast of Georgetown, Ohio. Center—38° 52.6′ N., 83° 52.7′ W. Looking southwest.



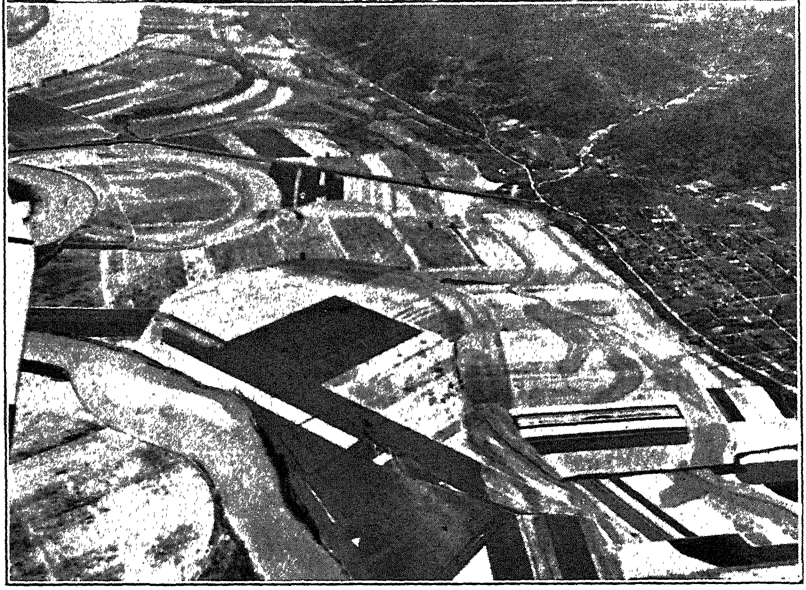
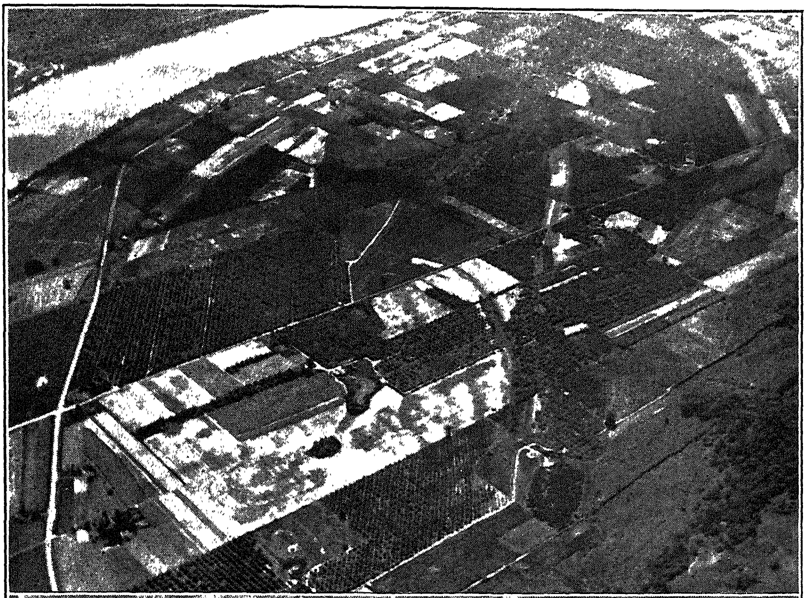


Fig. 3 (upper). Floodplain of Scioto River south of Waverly, Ohio. Looking north. Center—39° 5.5′ N., 83° 00.5′ W.

Fig. 4 (lower). Floodplain of Scioto River near its junction with Ohio River. Looking south. Center—38° 44.9′ N., 83° 1.0′ W.

PLATE III



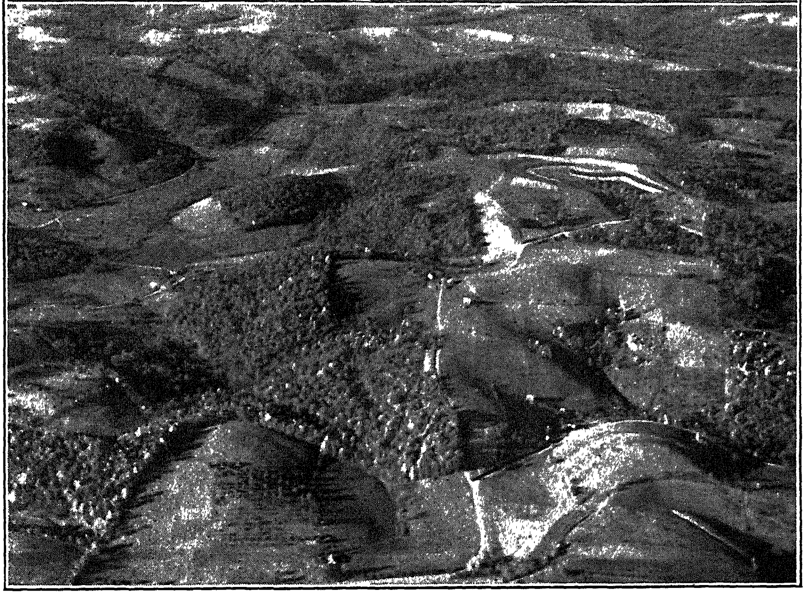


Fig. 5 (upper). Orcharding on floodplain and terrace of Ohio River about 7 miles east-northeast of Huntington, W. Va. Looking southwesterly. Center—38° 27.5′ N., 81° 20.5′ W.

Fig. 6 (lower). Typical unglaciated plateau of eastern Ohio 1¼ miles southwest of Freeport, Harrison County. Looking north. Center—40° 2.5′ N., 81° 17.1′ W.

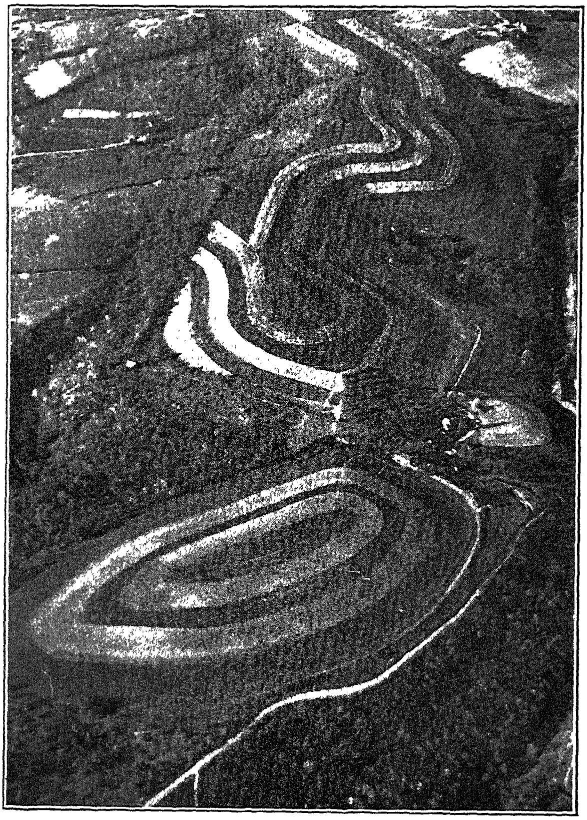
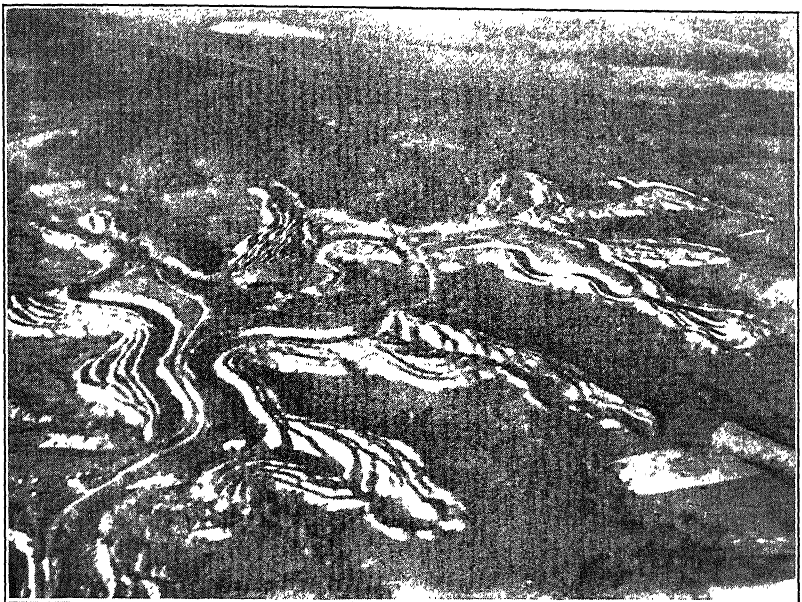


Fig. 7. Strip cropping to control soil erosion on the unglaciated Allegheny plateau. Looking north about 3 miles northwest of Avella, Pa., about one mile east of the West Virginia line. Center—40° 18′ N., 80° 30′ W.



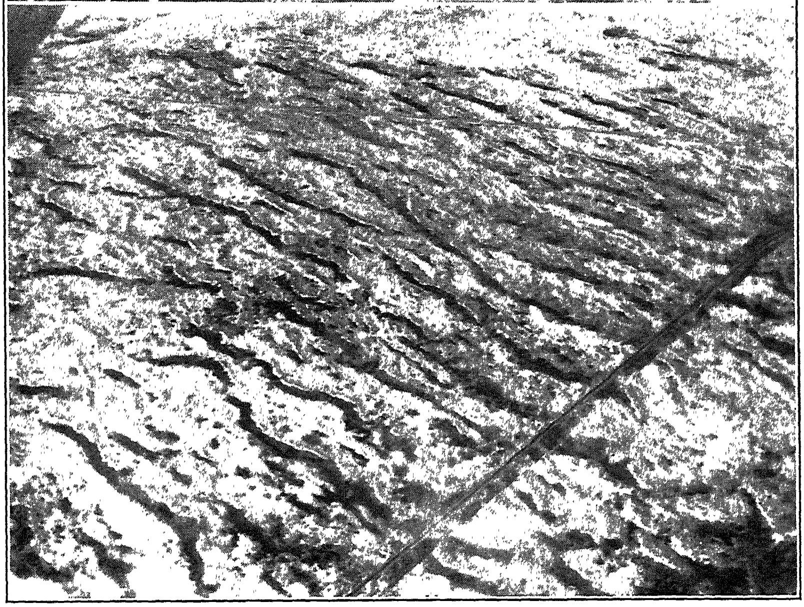


Fig. 8 (upper). Strip mining for coal in eastern Ohio. Looking northeast at large mine four miles south of Dresden, Muskingum County.
Center—40° 4.1′ N., 82° 2′ W.

Fig. 9 (lower). Sand hills along east side of Canadian River north of Clear Creek, Hemphill Co., Texas. Looking northerly from 35° 57′ N., 100° 15.3′ W.

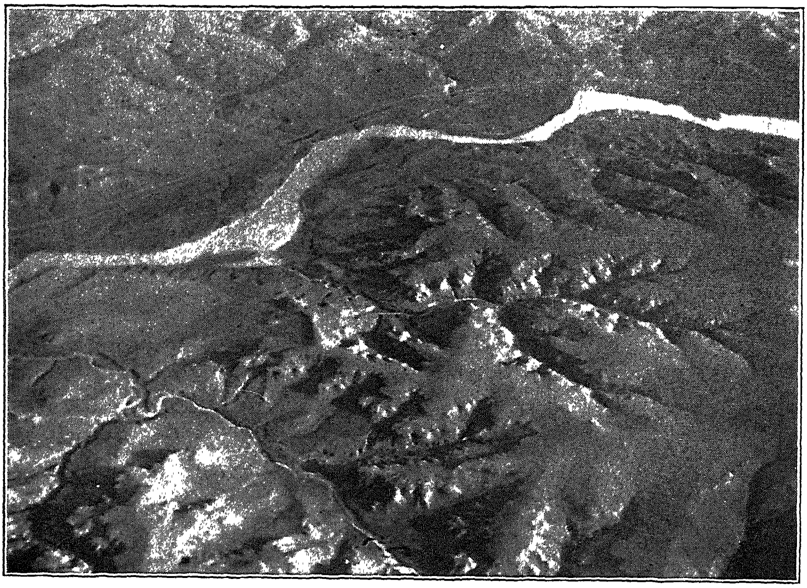


Fig. 10. Study in erosion along Red Deer Creek, Roberts County, Texas, about five miles northwest of Miami. Looking southerly from 35° 43′ N., 100° 43′ W.

POSTGLACIAL VEGETATION IN THE ERIE-OHIO AREA

PAUL B. SEARS
Oberlin College

It is fitting that the Golden Anniversary program of this Academy should devote some time to the problems of Ohio vegetation. The diversity of natural vegetation in Ohio has interested observers from the days of the first explorations down to the present. Before the founding of the Academy, surveyors, geologists, and botanists all contributed to the record. A notable instance was Dr. John L. Riddell (1) who saw in the prairies of Ohio a remarkable phenomenon.

In more recent years the Academy itself has generously encouraged studies of Ohio vegetation. Needless to say the pattern of this vegetation has had profound influence on the agricultural and industrial life of the state. During the past twenty years, beside the important work of Dr. Braun at Cincinnati (2), there have been numerous studies by Dr. Transeau and his associates at Columbus. These studies have had valuable results in their application to pest control (3). They have illuminated the work of a generation of young biologists who are now applying their knowledge to problems of land use and management throughout this and other states. I am glad to record such a debt to the Academy and the many colleagues who have labored in its ranks.

Some notion of the diversity of Ohio vegetation may be obtained from Figure 1, showing various types and their irregular pattern of distribution. It may be said at once that no simple factor can be adduced as an explanation. No map of climatic configuration that I have ever seen can be superposed on this map of original vegetation. One can, it is true, see evidence for some large physiographic influences, notably glaciation and lake retreat (4). Yet detailed profiles through various types of plant community certainly show that here again there is no simple relationship between topography and vegetation.

One needs no better evidence of the multiplicity of factors operative in the Ohio landscape than to see how comfortably—until the axe and plow destroyed them—species and communities of differing geographical and climatic affinities got on in close proximity.

Transeau's paper on the Prairie Peninsula (5) in addition to its clear formulation of numerous problems, has served to emphasize the relative and complex character of Ohio climate. As time goes on we shall learn much more about this matter from the studies now under way in the Muskingum watershed (6).

Author's Note: Since preparing the accompanying article, the writer has made an extended study of the literature dealing with the question of xerothermic postglacial climate. In view of recent evidences from Europe, the references in this paper to a xerothermic period ought not to be regarded as excluding the possibility of significant aridity earlier than the pine period here referred to. However, it should be stated that no American bogs thus far examined give any indication of such conditions.

At the other edge of the prairie, Weaver and Albertson (7) have shown how definite may be the effect on community composition of a few years of protracted drouth. And I may add that my own casual examination of tree rings in the Osage region indicates that recurring drouths, lasting from two to ten years, have characterized at least the past two hundred years.

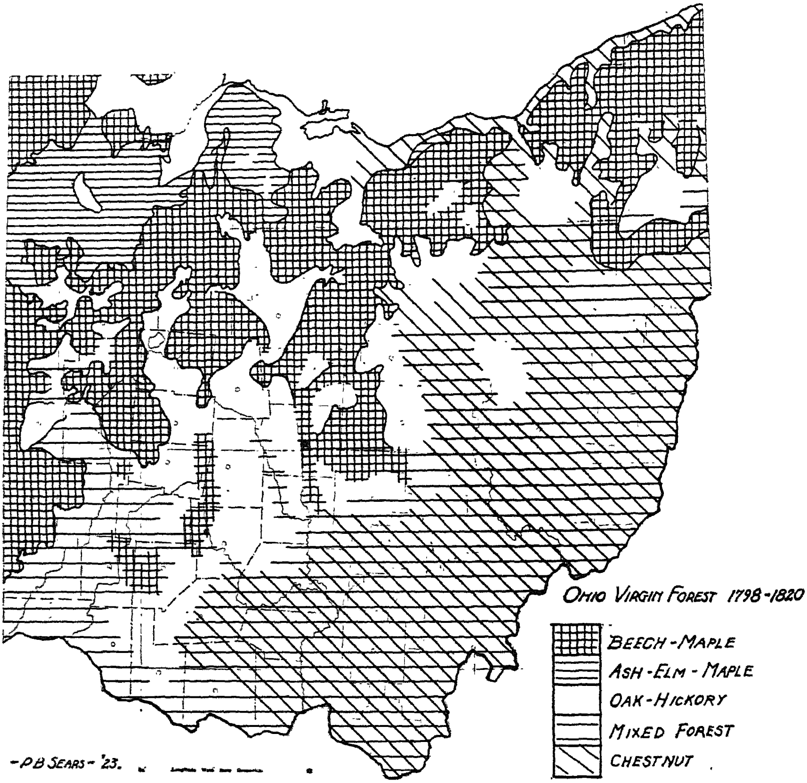


Fig. 1. A map of the original vegetation of Ohio based upon records of early surveys.

Because of the inadequacy of explanation based on existing conditions, students of vegetation have followed the steps of Asa Gray and other taxonomists in searching for historical data. In the case of Ohio, two important types of community—bog and grassland—present in a deciduous forest region have for many years emphasized the need for and importance of historical study.

Beginning in 1925 and for ten years thereafter, I employed the technique of pollen analysis in trying to trace the general course of vegetation changes throughout the Middle West. Several years were required for getting acquainted with the American pollen (8), a circumstance which materially slowed the procedure.

Taxonomists and others had already accumulated a good deal of evidence, not only of migration in the wake of the retreating glacier but of postglacial changes which involved east-and-west shifts of vegetation (9), presumably due to changing humidity of climate. The former presence of coniferous forests in Ohio and elsewhere in the deciduous forest region was readily established by pollen analysis. Its demonstration is now a routine experience which can be used as a laboratory exercise. Wherever there is a peat deposit whose sedimentation began in late glacial time, the presence of abundant coniferous pollen can be shown by microscopic examination of the deep layers of peat or marl.

It happens that the first bog I studied was likewise the oldest, situated on the crestline of the state, east of Bucyrus (10) (Fig. 2). The record here begins with an abundance of fir, gradually shifting to spruce, and then to pine. The pine in turn is replaced by increasing amounts of hardwood pollen, but the record is not complete because the top of the deposit has been destroyed.

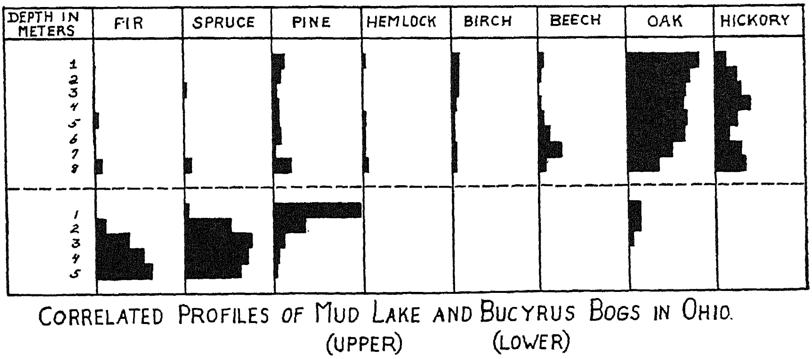


Fig. 2. Combined pollen profile of Bucyrus (lower) and Mud Lake (upper) bogs.

This pine maximum toward the end of coniferous time is widespread, and was interpreted, correctly, I still believe, to indicate a period of increasing aridity.

Subsequent analyses of bogs in deep kettle-holes, where peat formation has gone on more or less continuously up to the present, indicated that the deciduous period has been much more prolonged than we were to suspect from the truncated record of the Bucyrus bog. One of the best examples of this is the Mud Lake Bog in Ashland County (11). Among our unpublished records of some 25 bogs, however, we have found ample confirmation. This is also generally true of profiles that have been published by the growing number of other workers throughout Eastern North America.

Taking the Mud Lake Bog as an example (Fig. 2), we find a strong showing of beech and hemlock at the beginning of deciduous time, then once again in recent layers, a behaviour paralleled by the record of birch.

Hickory, however, shows a reciprocal curve, being strongest about two-thirds up from the bottom, when beech and hemlock were greatly reduced.

Here again we reasoned that the beech and hemlock, replacing pine, indicated warming and increased moisture. Above that point the hickory maximum we interpreted as a second dry—but now warm—interval whose waning was marked by the return of beech and hemlock. If our reasoning was correct, we had established the existence and position of the elusive xerothermic period postulated by Gleason (9) and others as an explanation of the prairie relicts east of the present prairie.

Let me acknowledge that this was dangerous reasoning, based on a minimum of evidence. In justification let me say that the profiles, instead of being erratic, showed long consistent drifts in the course of change, and that the genera we were using are excellent climatic indicators. It is of interest that Professor Fuller at Chicago, on first seeing it, pronounced the sequence obtained from the two bogs—Bucyrus and Mud Lake—an excellent confirmation of the Blytt-Sernander hypothesis of postglacial climate that had been developed in Europe (12).

Two problems immediately presented themselves. One was that of confirming or disproving the general sequence. The second was that of chronology. The first problem required the widescale study of peat profiles and their comparison. This had to be done as rapidly as good work would permit, and to that end a considerable number of other workers were given assistance in learning the proper technique.

It is of course clear that no analysis is complete without supplementary study of the basin from which the peat comes. But the basins will keep, and the peat frequently in these days of rapid exploitation will keep, and the peat in these days of rapid exploitation frequently will not. For that reason, our first objective was to secure just as many pollen profiles as possible.

The results of these studies showed clearly enough that there are definite regional types of peat profile, with their characteristic pollen trends. Furthermore, the presence of an early dry—cool—pine period seemed to be pretty general in the older, longer profiles. Above that, corresponding to the Mud Lake hickory maximum, presumably warm-dry, many at least of the profiles showed a maximum of oak as compared with more mesophytic species. The most important exception seemed to be the findings of Voss in Lake County, Illinois, to which further reference will be made.

As to the problem of dating, we did as others have had to do: used what means we could, pending the time when an accurate varve chronology would be afforded to us. So we obtained by three independent means some notion of the normal rate of peat accumulation. Knowing full well that this sort of measure has to be used with the utmost caution, we at least obtained estimates which indicated that we were dealing with magnitudes of the same general order as the precisely dated European records (13).

Meanwhile criticism arose from several sources. Doubt was expressed concerning the dependability of our counts, based on 100 to 200 grains per sample. As a result, Barkley (14), working in Oklahoma, made a study of the statistical principles involved and showed clearly that no practical gain may be expected by counting more than 150 grains per sample.

The second criticism was based on the studies of Voss (15) in Illinois, already referred to. It has been urged by Fuller (16) so that some attention should be given to it here. The Lake County profiles of Voss showed a replacement of conifers by deciduous forests, mainly oak, at the end of the first third of the record. Thereafter the deciduous forms exhibited what seemed to be an irregular fluctuation, giving no clear evidence of any climatic or vegetational change.

It should be noted, however, that Voss' own profiles from farther north showed a concave conifer curve, increasing at the top, complementary to a convex deciduous curve. This would appear to agree in general with either (a) the upper portion of our Ohio curves, or (b) with our whole curve if we assumed that the humid beech-hemlock interval was merely a local phenomenon.

To allow for this possibility, and to afford a scheme that could be definitely tested, I then proposed an hypothesis that postglacial time had been marked by a long period of warming and perhaps drying, up to a maximum from which it has since receded (17).

This of course does not take care of the Lake County bogs. But in explanation it must be said that there is no means of distinguishing the species of oak in these profiles from Illinois. And anyone who knows the oak-hickory region is well aware that red oak is more mesophytic than certain members of the white oak group. A fluctuation from red oak to white oak or vice versa in this region would be very significant if we could demonstrate it. But with all species of oak necessarily lumped, any such phenomenon would remain masked.

Furthermore, these profiles contain no mention of grass pollen, although it usually is pretty well preserved and should be of the greatest importance in indicating fluctuations at the margin of the grasslands. So far as climatic evidence is concerned, then, my own judgment with regard to the Illinois bogs is to recognize that they fail to support the xerothermic idea. What they might reveal if the species of oak could be determined and if grass pollen could be found in them would be of great interest and value.

Meanwhile, serious considerations were brought forward by the thorough studies of Wilson in Northwestern Wisconsin (18), where pollen profiles had been studied with reference to the recessional stages of Lake Superior and the present-day plant successions. In general the profiles fitted into the series obtained by workers from Minnesota eastward through Quebec. Predominantly coniferous at the base, they exhibited a slight shift toward oak at higher levels, followed by a recent increase in spruce, i. e., a return of conifers. Yet when compared with current successional changes these profiles in Wisconsin seemed explicable in terms of local plant succession under a climate like the present.

Without some basic climatic change, however, one would scarcely expect to find such a remarkable parallel trend in local succession on a front extending from the northern Great Lakes to the Atlantic. Moreover, both in Europe and America the sequence, conifer-hardwood-conifer, has been established as characteristic of interglacial periods, one of which the present may well represent.

It is of the greatest interest, therefore, to know that a recent study[1] of Ohio peat deposits has enabled Wilson to correlate them with the Wisconsin profiles and confirm the fact of recent climatic change, including a xerothermic period corresponding to the oak maximum noted by him.

Meanwhile it is in order to present the results of further study at Oklahoma, Oberlin, and Yale. Miss Eleanor Galloway who had been trained with Dr. Wilson was given access to much of my unpublished material and found a definite relation between profile type and bog location. Her manuscript is not now at hand, but as I recall it, a line approximating the Fourth Wisconsin Substage limit is roughly a boundary south of which are bogs whose profiles are mainly deciduous, while those to the north are largely coniferous. Mixed types are intermediate in position.

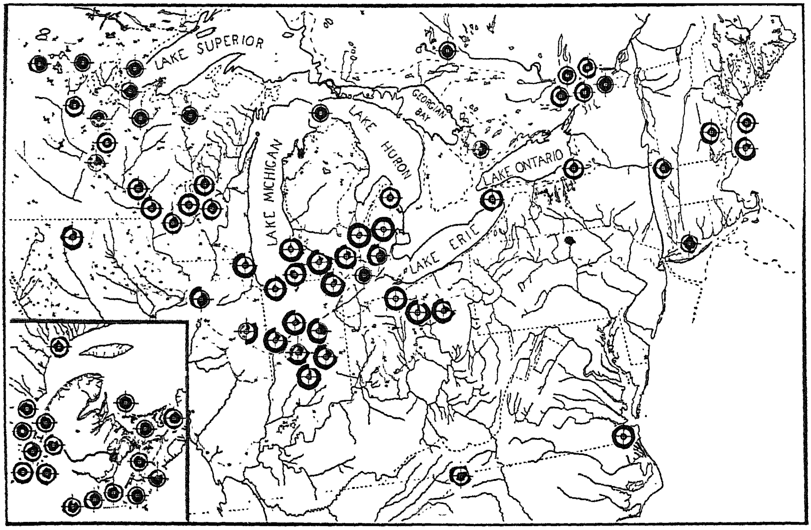


Fig. 3. Clock diagrams showing postglacial changes in frequency of conifers (inner circle) and deciduous (outer circle) trees. (From Preston Smith.)

Last year this problem of correlation was resumed by Mr. Preston Smith at Oberlin, our immediate aim being to trace the course of postglacial migration of certain trees. First compiling a critical map of glacial boundaries, data from nearly 70 bogs were assembled and plotted in the form of clock diagrams. Proceeding clockwise, these circles show the changing frequency from bottom to top of the bog.

The first of these shows the relative position and abundance in each profile of conifers (inner) and deciduous (outer) species (Fig. 3). The second gives the same information for hemlock (inner) and beech (outer) (Fig. 4). No correction is made for differences in time represented by a given profile, except as this is indicated by the position of each bog.

---

[1] Unpublished. Not seen until after this paper was read before the Academy.

Yet the map shows very clearly the location of Miss Galloway's deciduous, mixed, and coniferous profile types with reference to glacial retreat. Likewise the southwesterly movement of *Tsuga* and the northerly movement of *Fagus* are evident.

Further light on postglacial migration is available by taking five representative genera, *Tsuga*, *Quercus*, *Fagus*, *Carya*, and *Tilia*, and noting the order of their appearance in as many profiles as possible. Plotting this data for each genus separately, a series of contours is obtained indicating the direction of its postglacial advance. For graphic purposes, the area in which it was earliest has been indicated in black. This is assumed to represent, in general, the "center" of its postglacial distribution. Except for *Quercus* and *Carya*, the present range limits of each are indicated by a dotted line.

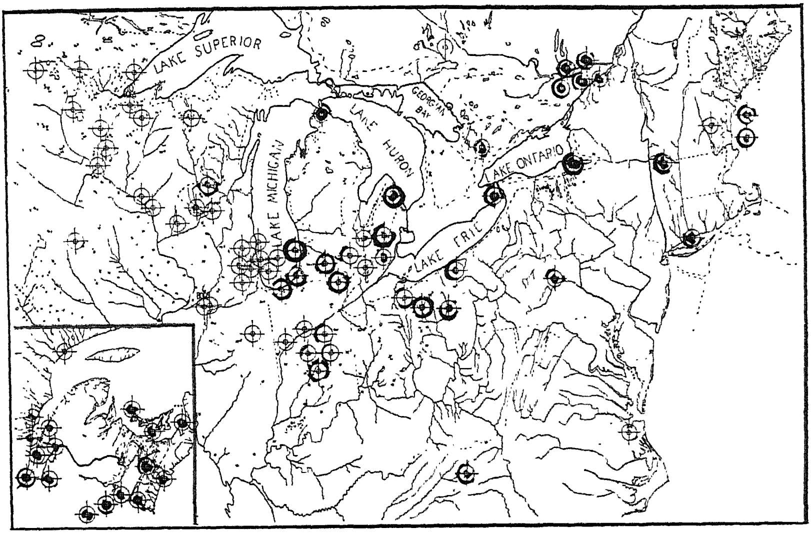
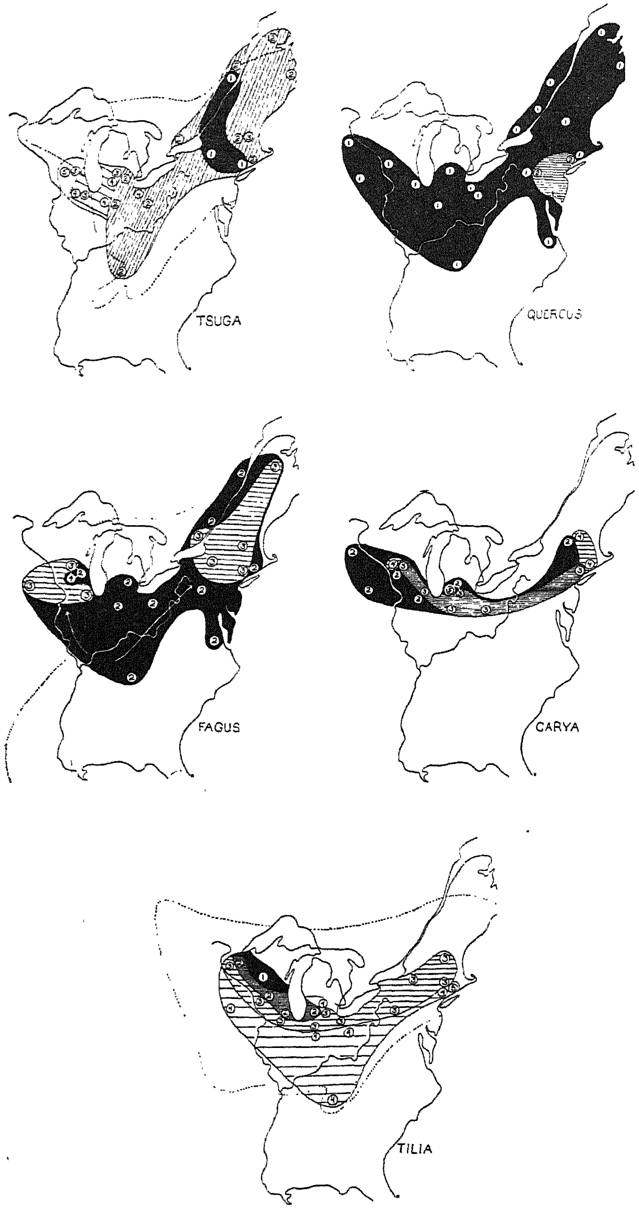


Fig. 4. Clock diagrams showing postglacial changes in frequency of hemlock (inner circle) and beech (outer circle). (From Preston Smith.)

The dispersion of *Tsuga* westward and northeastward from the New England area is apparent from Figure 5. Further pollen analyses, such as the unpublished work of Cain in the South Carolina Piedmont, will shed light on the late glacial movements of this genus north into New England. Undoubtedly former land areas now submerged were involved in this late glacial migration, preceding the postglacial movement shown on the map. For *Tsuga* is well established in the Southern Appalachians and certainly must have been there throughout the Wisconsin glaciation.



Figs. 5–9. Order of postglacial appearance of five important genera. Numbers indicate relative order of each in the series of five.

It is noteworthy that *Quercus* (Fig. 6) was first of the five everywhere except in the region where *Tsuga* had that position, centering about Long Island. The general northward advance of *Quercus* in postglacial times is evident, and in keeping with the size and complexity of that genus.

The diagram for *Fagus* (Fig. 7) clearly suggests a general northerly advance. The presence of *Fagus* in the Arkansas-Oklahoma boundary, and of sugar maple relicts 200 miles further west indicates that the Southwest, as well as the Appalachians, may have been an important place of retreat during glaciation.

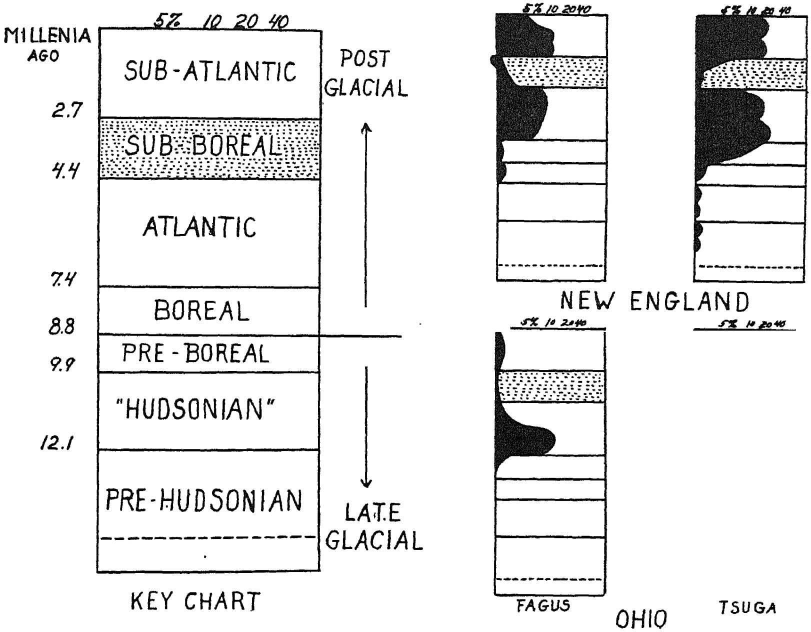


Fig. 10. Correlation of American and European chronologies with sample profiles for *Tsuga* and *Fagus* from New England and Ohio. Note minima for both genera during Sub-Boreal (xerothermic period). (From Preston Smith.)

Moreover a westerly center for *Carya* (Fig. 8) is suggested strongly, but as in the case of *Fagus*, we need more data from places like southern Illinois.

The diagram of postglacial migration for *Tilia* (Fig. 9) shows a definite movement toward the East and South. This also raises questions regarding a westerly glacial refuge. Certainly *Tilia* is today a dominant in the transition forests at the margin of the grasslands in Eastern Nebraska.

Finally I have permission to draw upon the data accumulated by Mr. Preston Smith (18). Using the varve counts of Antevs, north from New England, he has connected bog sedimentation with a definite postglacial chronology. He has also correlated bog reports over a wide area, having developed a method of plotting a particular kind of pollen in terms of its own frequency.

His scale is shown in Figure 10. For our purpose its most significant use is in confirming the existence of a warm-dry (xerothermic) period, the Sub-Boreal, as well as the general migration facts for beech and hemlock already indicated in this paper. The Sub-Boreal, it will be noted from the figure, is marked by a definite reduction in beech and hemlock, as compared to more xeric forest trees.

SUMMARY

This paper discusses the evidence from pollen analysis which establishes the existence of a postglacial warm dry period in eastern North America. This period has been an important factor in the pattern of present day native vegetation. The migrations within the glacial area of *Quercus*, *Tsuga*, *Fagus*, *Carya*, and *Tilia* are also traced. In general terms, the advance of *Quercus* and *Fagus* was northerly. *Tsuga* was dispersed from the northeast; *Carya* and *Tilia* from the west.

PAPERS CITED

(1) **Riddell, John L.** Report of John L. Riddell, M. D., etc., Rep. 60 to Gov. and Legisl. Ohio. 1837.
(2) **Braun, E. L.** The Differentiation of the Deciduous Forest of Eastern United States. (This issue of Ohio Journal of Science.)
(3) **Transeau, E. N.** Vegetation Types and Insect Devastations. Ecology 8 (3): 285–88. 1927.
(4) **Sears, Paul B.** The Natural Vegetation of Ohio. Ohio Journal of Science 25 (3): 139–149. 1925; 26 (3): 128–146, (4): 213–231. 1926.
(5) **Transeau, E. N.** The Prairie Peninsula. Ecology 16 (3): 423–37. 1935.
(6) **Thornthwaite, C. W.** Microclimatic Studies in Oklahoma and Ohio. Science 86 (2222): 100–101. 1937.
(7) **Weaver, J. E., and F. W. Albertson.** Major Changes in Grassland as a Result of Continued Drought. Bot. Gaz. 100 (3): 576–91. 1939.
(8) **Sears, Paul B.** Common Fossil Pollen of the Erie Basin. Bot. Gaz. 89: 95–106, 3 pl. 1930.
(9) **Gleason, H. A.** The Vegetational History of the Middle West. Ann. Assoc. Amer. Geog. 12: 39–85. 1923.
(10) **Sears, Paul B.** A Record of Post-Glacial Climate in Northern Ohio. Ohio Journal of Science 30 (4): 205–17. 1930.
(11) **Sears, Paul B.** Pollen Analysis of Mud Lake Bog in Ohio. Ecology 12 (4): 650–55. 1931.
(12) **Sears, Paul B.** Climatic Change as a Factor in Forest Succession. Journal of Forestry 31 (8): 934–942. 1933.
(13) **Sears, Paul B., and Elsie Janson.** The Rate of Peat Growth in the Erie Basin Ecology 14 (4): 348–355. 1933.
(14) **Barkley, Fred A.** The Statistical Theory of Pollen Analysis. Ecology 15 (3): 283–289. 1934.
(15) **Voss, John.** Postglacial Migration of Forests in Illinois, Wisconsin, and Minnesota. Botanical Gazette 96 (1): 3–43. 1934.
(16) **Fuller, George D.** Interglacial and Postglacial Vegetation of Illinois. (Address of the retiring President of the Illinois Academy of Science, presented at the Thirty-second Annual Meeting, Springfield, Illinois, May 5, 1939.) Transactions of the Illinois State Academy of Sciences 32: 5–15. 1939.
(17) **Sears, Paul B.** Climatic Interpretation of Postglacial Pollen Deposits in North America. Bul. Amer. Meteor. Soc. 19: 177–185. 1938.
(18) **Smith, Preston.** Correlations of Pollen Profiles from Glaciated Eastern North America. American Journal of Science, 238: 597–601, August, 1940.

THE DIFFERENTIATION OF THE DECIDUOUS FOREST OF THE EASTERN UNITED STATES

E. LUCY BRAUN,
University of Cincinnati

Deciduous forest originally covered a large part of the eastern United States. A certain unity is given to the formation by the dominant life form and by some of the wide-ranging genera and species. However, it is not uniform throughout, but differs in different geographic sections in its composition and dominant trees. Why? Because conditions are or have been different in different parts of the area.

Forests develop. Any change in environment causes a change in vegetation. Such vegetational changes are usually gradual and may be local or widespread depending on the magnitude of the causal factor. The reactions of occupying vegetation produce changes, gradual development. Soils undergo modifications hand in hand with vegetational change, from the time of their origin from parent materials, to the ultimate development of mature soil of a regional type. The progress of erosion cycles is accompanied by vegetational change; youthful, mature, and old age stages of the erosion cycle are vegetationally different. The environmental features of the peneplain are different from those of a mountain range or strongly dissected plateau. Continental configuration changes; here coast lines rise and continental shelves emerge; there coasts are drowned and erstwhile parts of continents submerged. Such continental change must result in vegetational change—in migration and shifts in the ranges of species and hence in the composition of communities. Climates change, becoming more humid or less humid, warmer or colder. Every change in climate is accompanied by changes in vegetation and shifts in vegetational boundaries.

The record of vegetational change or development may be preserved in fragmentary communities preserving earlier successional stages, in isolated (relic) communities apparently not in complete accord with existing conditions, in disrupted ranges of species or groups of related species, and in fossils. All of these we must use if we are to trace the changes which have taken place in extent and composition of our deciduous forest.

Differentiation of the eastern deciduous forest is a result of forest development and change in response to these (above mentioned) changing local and regional enviroments, both present and past. The great area occupied by deciduous forest is not all of the same age, nor has it all had the same history.

The Appalachian upland has been continuously available for forest development since the origin of angiosperms, now the most important constituents of deciduous forest. Its central part, especially the western slope of the unglaciated Appalachian upland, is remarkable for the diversity of aspect of its forest, which results from the large number of species and innumerable variations in groupings of species. Here is preserved a large remnant of ancient forest, of the forest of the Tertiary age. Many of its genera and some of its species are common to this area and to the deciduous forest of Asia, two areas between which there has been no connection since late Tertiary time. Can species persist this long? The paleontological record, although very inadequate for the East, nevertheless gives evidence that they can. There are recognized instances of specific identity of Miocene and existing plants. No adequate picture can be had of deciduous forest without emphasis of its central part, no reconstruction of the history resulting in its present differentiation is possible without a knowledge of this central part, this remnant of, or lineal descendant of, the Tertiary forest.

Mixed deciduous forest occurs throughout the unglaciated Appalachian upland, and to some extent beyond it. However, only in certain parts, especially the Cumberland Mountains and southern Allegheny Mountains, and adjacent Cumberland and Alleghany Plateaus,[1] does the mixed forest that we know as *mixed mesophytic forest* prevail. Vegetationally, this is a forest made up of some twenty or twenty-five species, a forest without definite dominants, or with several important species, rather than only one or two. Slight environmental differences in the optimum area of mixed mesophytic forest result in segregation of its species into more or less well marked communities. Certain of these communities belong to drier sites—ridge tops and steep southwesterly slopes. Others reflect altitudinal influences. But even where altitudinal range is slight and extremes of moisture absent, variations in forest composition occur, and distinct association-segregates may be recognized.

Going away from the center, or region of best development of the mixed mesophytic forest, we find a tendency toward greater uniformity of type; that is, there seem to be fewer segregates in the mixed mesopytic forest. Gradually, in all except a northerly direction, the mixed mesophytic forest becomes more and more limited to favorable sites, lower ravine slopes, coves, gorges. More and more of the area is occupied by some type of forest not readily referable to the mixed mesophytic association.

Let us consider a few forest areas situated on radii diverging from the center of mixed mesophytic forest. This will illustrate the change in composition so evident in all directions.

Southward, in the region of the higher southern Appalachians, the significance of the forester's term, "cove hardwoods," becomes apparent. "Cove hardwoods" and mixed mesophytic forest are one and the same, but here in the mountains of eastern Tennessee and western North Carolina, the mixed mesophytic forest is largely limited to coves. The Joyce Kilmer Forest in North Carolina contains a much higher percentage of chestnut than is found in the typical mixed mesophytic forest. In the Great Smoky Mountains, mixed mesophytic forest occupies the coves and deeper valleys, chestnut is (or rather was) important over a much larger part of the mountain slopes than in the Cumberland Mountains.

---

[1] Physiographic regions are used as defined by Fenneman, N. M., Physiography of eastern United States, McGraw-Hill Co., 1938.

Eastward, in the George Washington National Forest in Virginia, on one of the ranges of the Ridge and Valley Province, we find an apparently mesophytic forest tract which is quite evidently the oak-chestnut-tulip tree type distinguished on some vegetation maps. Farther east, on the Blue Ridge of Virginia, we find (in White Oak Canyon) a mixed forest which is about half oaks and chestnut. Both of these forest tracts are in situations in which any one familiar with the mixed mesophytic forest would expect to find that association. Yet both of these, though mixed forests, might be considered as belonging to the oak-chestnut association. In the narrow gorge of Ceder Creek near Natural Bridge, Va., is forest which is definitely of the mixed mesophytic type. Farther east, on the Piedmont, the prominence of oaks is well known.

Southwestward, toward the southern end of the Cumberland Plateau, the slope forest has a lower percentage of the typical trees of the mixed mesophytic, especially basswood and buckeye, and a higher percentage of oaks, although the forest still retains the aspect of the mixed mesophytic forest, and typical stands of that forest occupy the most mesophytic slopes.

Westward, too, we find this limitation of mixed mesophytic to the most favorable sites. For instance, in the gorge of Clifty Creek in Todd County in western Kentucky, there is good mixed mesophytic forest with a high percentage of beech. Forests of ravine slopes in the Mammoth Cave region contain many of the trees of the mixed mesophytic forest, yet there is a pronounced increase in oaks and hickories. In the Ozark region of Missouri and Arkansas, there is no question but that oak-hickory forest is the prevailing association. Nevertheless there are small areas of forest in this region—in canyons and deep valleys—which closely resemble the mixed mesophytic forest to the east.

What is the situation northward? Mixed mesophytic forest extends through the mountains of West Virginia and into Pennsylvania, gradually changing because of the increased importance of maple and beech, and because of an admixture of more northern species, to the northern beech-maple forest or to the hemlock-white pine-northern hardwoods type, or northeastward, to the "mixed transition forest" distinguished by foresters.

Where the boundary of Wisconsin glaciation is reached, whether it be in western New York State or in Ohio, anywhere west of the longitudinal ranges of the Alleghanies, there is an abrupt change in forest composition. Beech and sugar maple at once assume greater importance than in the mixed mesophytic association. The area of the beech-maple climax has been reached. Farther west, in Indiana, there appears to be a division of dominance between beech-maple and oak-hickory, beech-maple generally occupying the more mesophytic sites.

Let us try to reconstruct the events which lead to the present forest pattern. Fossil records show that a broad-leaf forest, with many existing genera, and hence a mixed forest, extended across the now prairie and plains states in late Cretaceous and early Tertiary time. These early forests contained also representatives of many genera not now found in the forests of north temperate regions today, for the climate for at least part of that time was probably milder than now.

Zonal shifts in vegetation, readjustments of species distribution, doubtless accompanied the cooling of the late Tertiary. The Rocky Mountains began to rise (in post-Cretaceous time), and the land to the east of them was deprived of rain-bearing westerly winds. The drying continental interior was no longer suitable to deciduous forest and its boundary receded eastward contemporaneously with the development of the great interior grassland. Increasing aridity in the interior meant the withdrawal of the most mesophytic tree species, while those of lesser moisture requirements found the somewhat diversified topographic conditions of the Ozark Upland favorable. This then became the stronghold for what is now known as the oak-hickory forest. (Other east-west shifts in forest and forest species have of course taken place, at least some of which are Pleistocene or later.)

The mixed forest for the most part retreated to the east of the Mississippi River, although, as has been mentioned, remnants of that forest are seen in isolated situations in the Ozarks, and curiously enough, on Crowley's Ridge, a low ridge of Tertiary age rising above the wide alluvial flood-plain of the Mississippi River.

Cycles of erosion, resulting in peneplains more or less extensive, were affecting the eastern forest area, for slopes change and soils change with the progress of the erosion cycle. Unreduced areas, on an otherwise peneplained surface, afford habitats not general on the peneplain. Hence these sloping areas could have been, and probably were, the most favorable sites for mixed forests similar to those which now occupy slopes. Uplift brings about renewed erosion and renewed soil development. Much of the land surface will again be sloping. Remnants of old peneplains will remain, and parts of newer ones be forming.

The physiographic features of the East are in large measure due to the work of two erosion cycles, resulting respectively in the Schooley and Harrisburg peneplains. Today, over the great area where the upland levels represent the reduced Schooley peneplain, and where no later peneplain was extensively developed, the mixed mesophytic forest prevails.[2] This is an area, for the most part, of mature topography.

The development of a later peneplain—the Harrisburg and its more or less contemporaneous representatives in the interior—again curtailed the area occupied by mixed forests of slopes. Subsequent erosion has considerably dissected the interior representatives of this peneplain, but has little affected the broad valleys of the Ridge and Valley Province.

Cycles in soil development must have more or less paralleled these cycles of erosion. Young soils, showing the characteristics of their parent materials, will cover newly eroding slopes. As time goes on, the soils will become mature, will reach "a stage of development marked by the practical absence of geological features."[3] Such soils, and only such, can support the regional climax vegetation. Soils may become old, and lose some of the essential characteristics of normal soils of their climatic region. Such old soils generally "occupy old flat surfaces of earlier topographic cycles where they have been undisturbed for long periods of time."[4] As most of the former Schooley peneplain has been reduced to slopes, few if any such old soils occur; most of the soils are mature. Many parts of the Harrisburg peneplain, however, are still flat. The forest of these areas in places seems out of accord with the regional type. White oak is the dominant tree.

---

[2] Some may wish to include additional peneplains, and assign to the Allegheny or even to the Harrisburg peneplain, the upland levels of the Appalachian Plateau in eastern Ohio. Whatever peneplain interpretation may be followed, the correlation between the area of mixed mesophytic forest and the oldest peneplain of the Plateau remains.

[3] See Wolfanger, Louis A., The major soil divisions of the United States. John Wiley & Sons. 1930.

Glaciation was a major event affecting the forests of eastern United States. Only 30,000 years, more or less, have been available for the revegetation of the glacially denuded land; only a fractional part of this time has been available for deciduous forest development. This is in contrast to the millions of years of undisturbed occupancy of the unglaciated land to the south, occupancy of course affected by cycles of erosion and of soil development. After long developmental stages, climax forests have in places become established in the glaciated territory, although in much of the area development is still in progress, species ranges are shifting. Due to the limitations of climate, of soils, of migration capacities, all of the species involved have not moved equal amounts or at equal rates. The post-Wisconsin xerothermic period favored an eastward movement of the constituents of the oak-hickory forest migrating northward from the Ozark upland. It thus became established in the western part of the now forested glaciated territory. The maximum movement of the more mesophytic species was to the east of the prairie lobe. Thus arose the beech-maple forest, so well represented in parts of Michigan, Indiana, Ohio, and western New York.

Ecologists generally recognize four major subdivisions or climax associations of the deciduous forest: mixed mesophytic, oak-hickory, oak-chestnut, and beech-maple. The areal distribution of each of these is related to climatic and physiographic features, past and present, and the inter-related process of soil development.

The mixed mesophytic association occupies a central position in the deciduous forest. This is a region of moderate to high rainfall, of cold, though not extreme winters. The area of its best development, the Cumberland Mountains and Cumberland Plateau and southern Allegheny Mountains, is an area of mature topography, for the most part the area of the reduced and dissected Schooley peneplain. Within this area the complex mixed forest displays many segregates demonstrating the sensitiveness of its constituents to minor variations in environment—microclimates and soils, both of which are affected by physiographic history. The extent of mixed forest (of which our mixed mesophytic association is a lineal descendant) has been curtailed in the past by climatic changes—increasing aridity in the west, and later, glaciation in the north. Its limits have been modified by the progress of erosion cycles, by the progress of soil development and the establishment of zonal soil types. None of these influences has brought about sharp areal limits of the mixed mesophytic association. Yet certain correlations may be pointed out. The Allegheny Front, and southward, the Cumberland Front, form the eastern boundary of the area where mixed mesophytic forest prevails. East of this, except in the southern Blue Ridge, the land was profoundly affected by the Harrisburg cycle of erosion. The boundary of the Wisconsin ice sheet forms the northern boundary of mixed mesophytic forest, except that, in the higher longitudinal ranges of the Allegheny Mountains, transitional forest occurs. Roughly, the southern limit of the gray-brownerth, or the northern limit of the red-and-yellowerths, forms the southern boundary of the mixed mesophytic association. This soil boundary reflects a climatic boundary, for the red-and-yellowerths are the result of the open winters of the climate in which they have developed. The red-and-yellowerths are poorer soils than the gray-brownerths and do not support the mixed mesophytic forest. On those poorer soils, oak-hickory forest, or in places oak-chestnut forest prevails. Along the western edge of mixed mesophytic forest is a broad transition belt. There is no zonal soil line, no line related to a past erosion cycle. The climatic limit, in the absence of other factors affecting or affected by climate, is indefinite. Within the area of the mixed mesophytic association, both oak-hickory and oak-chestnut forest occur. That neither is climax in this area is at once evident from the fact that both occupy either immature soil areas, ridge tops or dry slopes on which the soil does not have the normal soil profile, or old soils of a former topographic cycle. Which type is present on a ridge or slope depends upon the nature of the underlying rock—certain evidence that neither is climax in the area of the mixed mesophytic association. In the climatic areas in which these prevail, this relation to underlying rock does not exist. The mull type of humus layer prevails in mixed mesophytic forest.

---

[4] Wolfanger, loc cit., p. 13.

The oak-hickory association is to the west, northwest, and to some extent to the south of the mixed mesophytic association. The higher rainfall of its southeastward extension is compensated by the poorer zonal soil.

The oak-chestnut forest is, for the most part, to the east and southeast of the mixed mesophytic, although areas of typical oak-chestnut or oak-chestnut-tulip tree forest occur farther west. Throughout the extent of the oak-chestnut association (except perhaps far to the northeast) areas of mixed mesophytic forest are of frequent occurrence on mature soils of valleys dissecting the Harrisburg peneplain, and in coves on the long slopes between the Schooley and Harrisburg levels. This suggests, of course, that the boundary is not climatic, and that the oak-chestnut might be replaced by an extending mixed mesophytic forest. Such extensions have reached the outer edge of the coastal plain.

The beech-maple forest is the northern mesophytic expression of deciduous forest. The transition toward beech-maple demonstrated above 3000 feet in the Allegheny Mountains, shows the climatic relation between mixed mesophytic and beech-maple. The sharp southern boundary farther west, at the boundary of Wisconsin glaciation, is in part historic. This boundary may shift by invasion of additional mesophytic species. Northward, beech-maple gives way to the hemlock-white pine-northern hardwoods or lake forest. Westward, the boundary of beech-maple and oak-hickory is approximately the boundary of the prairie peninsula. Past and present climates have affected this boundary.

To summarize: All of the associations of the deciduous forest are genetically related. Within the area of the mixed mesophytic forest, association-segregates suggest the mode of origin of a variety of types from the mixed forest, and demonstrate the relationship of oak-hickory, oak-chestnut, and beech-maple forest to the mixed mesophytic forest. The differentiation which we see today is the result not alone of existing conditions, but also of past history, climatic and physiographic. The more or less gradual change in forest composition, from the area of mixed mesophytic forest outward in all directions, reflects the influence of past and present differences of environment. Transitions between associations are generally gradual, hence boundaries are indistinct. Yet these boundaries may in part be correlated with soil development and the establishment of zonal soil groups; with cycles of erosion; with changes in climate, increasing aridity in the interior and later, glaciation.

Insect Embryology

Much has been written concerning the development of individual insects, but few have been the attempts to summarize the data available. The present volume does not attempt to present all the available data but out of many years experience Professor Johannsen has been able to select judiciously that material which contributes to a clear picture of the field. The able assistance of Dr. Butt is demonstrated in the quality of the illustrations.

The arrangement of materials is unique. Part I is devoted to a summary of insect embryology. Types of cleavage in eggs; a type of embryonic development; fertilization, maturation and cleavage; early development; embryonic envelopes; gastrulation and germ layer formation; the alimentary canal; ectodermal derivatives; mesodermal derivatives; polyembryony; microorganisms in the egg; experimental embryology. These general topics are carefully treated, controversial points are recognized and various views presented. Numerous references to specific papers are appended to each chapter. Part II is devoted to discussion of the embryology of specific insects as representatives of groups. In this portion the whole of Class Hexapoda is surveyed. A discussion of the embryology of Myriapods conclude Part II.

This book is an invaluable contribution to the study and particularly the teaching of Insect Embryology. Both authors and the publishers are to be congratulated upon this notable volume.—*Paul E. Schaefer*.

Embryology of Insects and Myriapods, by Oskar A. Johannsen and Ferdinand H. Butt. 462 pages. New York, McGraw-Hill Book Company, Inc., 1941. $5.00.

RECENT TRENDS IN HORTICULTURAL RESEARCH

J. H. GOURLEY,
The Ohio State University

So rapidly do the different areas of plant science change and enlarge that I may be pardoned if I first attempt to express a viewpoint of what horticulture is, and thus account, in part, for the diversity of its activities in modern research.

It is indeed not easy to delineate horticulture, to hit on a definition that adequately expresses the modern concept of the word. One attempts to trace its boundaries only to discover overlappings in other fields, controversial spheres of influence. Yet there is a popular notion of horticulture which brings people to flower shows, to cherry blossom festivals, to the market place. That practical horticulture and research are inexorably bound together is a fact that cannot be ignored. So if I refer to practical matters it is not that I am trying to find a place to hide but because of a patent fact.

It must be obvious to anyone that horticulture has to do with certain kinds of plants or crops which have through long custom been associated with it. Furthermore horticulture represents a special type of viewpoint. This latter is rather intangible but none the less true. In the beginning horticulture referred to a garden, that is, to an intensive type of plant growing in contrast to the culture of field crops. This meant fruits, flowers, vegetables, and ornamental plants. It represented a certain refinement of agriculture which came with leisure or was associated with the home itself. As plantings were expanded for commercial purposes the old idea of interest in the individual plant was retained. Whether apple, potato, or rose farming is still horticulture might be debated by some. But certainly horticulture has emerged from a garden into a vast enterprise and includes such features as nursery practice, the growing of vegetable and flower seeds by the thousands of acres, the processing of canned and frozen foods, the manufacture of spray materials and fertilizers, as well as the growing of fruits, flowers, vegetables, and ornamental plants.

Finally, it must be pointed out that horticulture is both an art and a science. It was an art long before there was any science or any agricultural colleges, and the art will continue whether there is a science or not. It is practiced by the untaught and by those of the greatest learning and culture. That is, horticulture, the art, does not belong to horticultural departments, neither is it destroyed no matter into whose hands it may find itself for a time. It retains its distinctive features, no matter into what university melting pot it may be thrown.

Having expressed this as a background I will attempt to point out some trends in horticultural research. The cases have been selected at random and quite arbitrarily.

THE PLANT'S ENVIRONMENT

If we consider ecology as that branch of biology which deals with the mutual relations between organisms and their environment, then horticulture makes the widest use of it. Ordinarily we do not call the studies by this name, and perhaps a new term will be introduced which will refer more particularly to applied or artificial relationships. Some reference must, therefore, be made to the manipulation of environmental factors, particularly those that are within the hands of the operator. As Livingston says: In all our experiments the environment lurks behind the scenes, as it were, ever ready to baffle our efforts and always calling for very watchful alertness on our part.[1]

The grower of crops must deal with the environment below and above ground. As he changes the environment by cultural practices, whether it be tillage, irrigation, pruning, or spraying, he to some degree affects the plant behavior. Let us look briefly at some of the work along this line.

Temperature.—It is only in the greenhouse and in the refrigerated storage that much can be done about temperature. True, orchard heating is practiced in some sections, mulching is used in part to prevent great fluctuations in soil temperature, but in the main, the horticulturist must select varieties and cultural practices that give the least trouble. Temperature is, however, receiving considerable study and most marked effects are obtained. That temperature has an influence on growth, anatomy, and the metabolism of the plant is manifest.

An interesting and illuminating case of the effect of temperature upon the vegetative and reproductive phases of development is that reported for cabbage. Premature seeding or "bolting" of cabbage is of common occurrence. The cause was usually assigned to poor seed although it was known that early sowing of seed predisposed the crop to this trouble.

Work conducted under the direction of Thompson[2] at Cornell showed that "mature plants taken up in the fall before they were subjected to low temperature did not seed when grown subsequently in a warm greenhouse (60° to 70° F.), while those grown in a cool greenhouse (50° to 60° F.) produced flowers and seed. The plants grown continuously in the warm house produced three heads in succession during the first year. One of the plants was kept in the warm house for two years after it was brought in from the field in October, 1925, and this plant produced six heads. After the sixth head developed and the plant was about three years old it was moved to a cool house and within a few months it flowered. The plants used represented a pure-line strain so that all of them had the same genetic constitution."

The opposite of this situation obtains with lettuce, high temperatures favoring premature seeding.

In none of these cases has length of day been a factor.

With greenhouse plants grown for their flowers, equally interesting results have been secured. For instance, stocks, which also belong to the Criciferae, respond very similarly to cabbage, but since it is the flowers that are wanted the early "bolting" is desirable, and subjecting the seedling plants to low temperature may now be practiced.

---

[1] Livingston, Burton E., 1934. Environments. Sci. 80: 569–576.

[2] Thompson, H. C., 1939. Vegetable Crops. McGraw-Hill Co.

Bulbous plants also are treated to force early flowering. Daffodils and bulbous iris subjected to 50° F. before forcing will bloom about four weeks early. If tulips are first preheated at a low temperature of 75° to 80° F. and then subjected to a low temperature they can be advanced considerably in time of bloom. This work has been done in Holland, England, and America. Darwin tulips can be secured in this manner in November instead of February as had been customary.

Lilies do not initiate flower primordia in the bulb stage as do other bulbs; hence it is possible to subject the young plants when a few inches high to a temperature of 50° for about two weeks. Such treatment will increase the number of buds per stock.

If gladiolus corms are placed in a temperature of 75° to 80° for a month before forcing, that is, preheated, they will flower about a month early.

Equally striking anatomical differences may be noted at different temperatures.

Water.—Water is such a commonplace that one would not expect to pay attention to it unless there was a great surplus or deficiency. Yet a successful greenhouseman will tell you that one of the most difficult operations to teach to a beginner is that of watering the plants. The desired amount varies with the kind of crop, the weather, the season of the year, the stage of development of the plants, and the nature of the soil. Many a crop is ruined by the misuse of water.

We have always thought of water as "water," but there are those who say that now we must unlearn that. Quoting Professor Salisbury: "Much of the water we drink is not simple water, but double water composed of two H_2O groups linked together as dihydrol. What constitutes water in the state of ice is not known, but when ice melts the water which is released is neither simple H_2O nor the double brew, but is composed of three molecules linked together as trihydrol. Whether these variations on the simple watery theme have any significance in horticulture cannot yet be stated with certainty. It is true that when plants are watered with what is simple water, as, for example, water from condensed steam, they do not, so it is said, grow so well as when they are watered with melted ice water. . . . It is often claimed by gardeners, and probably the claim is sound, that heavy falls of snow have a beneficial effect on the subsequent growth of plants."[3] And so the simplest elements of the environment are in for re-examination in the light of their effect on plants.

An interesting case of research in regulating water supply is provided in studies with tomatoes. Limited watering which allows the soil to be alternately wet and dry results in a large percentage of the crop (more than 75%) being affected with blossom-end rot, whereas similar plants which are kept well supplied at all times show practically none of this trouble. In fact, this simple treatment has practically eliminated it from greenhouses.

---

[3] The plant and its water supply. 1938. Gard. Chron., March 19.

Light.—Following the classic work of Garner and Allard on the effect of length of day on plants, the horticulturist has made some practical use of this finding, notably with greenhouse crops. The chrysanthemum, being a short-day plant, was particularly amenable to treatment. Laurie and his associates[4] used black cloth to cover the beds in the greenhouse from 5:00 P. M. until 7:00 A. M. each day for a period of 30 to 35 days beginning July 15. This treatment has advanced the crop a month or more. On the other hand using electric lights to lengthen the day delayed flowering so that the mum season is now six instead of the usual three months.

Similarly, asters may be brought into bloom earlier by shortening the daylight period.

Just as shortening the day has induced early flowering of certain plants, so lengthening the day has had equally beneficial effects with certain other commercially grown flowering plants. The additional light should be applied from 5:00 to 10:00 P. M. or from 2:00 A. M. to 7:00 A. M. during fall and winter. Particularly responsive are *Lilium longiflorum*, annual chrysanthemum, *cineraris*, *Gypsophila*, and stocks.

Atmosphere.—It is not easy to regulate the atmosphere about plants and perhaps as conspicuous an example of efforts in this direction as might be cited is the use of modified atmospheres for the storage of fruit, or gas storage, as it is called in England. Trials have been made for years on the effect of artificial atmospheres in the storage and transit of fruits. As early as 1821 Berard was presented with a medal by the French Academy of Science for his paper on the storage of fruit in atmospheres devoid of oxygen, but it is only within the past few years that interest in the subject has developed from a commercial standpoint.

Smock[5] has described this type of storage and the results procured by it. He points out that respiration is diminished in intensity not only by lowering the temperature but also by reducing the amount of oxygen or allowing CO_2 to accumulate. Yellow Newtown apples held in CO_2 concentration of 10 per cent at a temperature of 45° F. were as green and firm as those held in air temperatures of 32° and 36°. Northwestern Greening apples after 30 weeks in 5 per cent CO_2 and 2.5 per cent oxygen (normal is 21 per cent O_2) at 40° F. were still as green as when first stored. Comparable fruit stored in normal air at 40° for the same period was completely broken down and worthless. Similar fruit stored at 36° was wholly unmarketable after 30 weeks because of softening, yellowing, and 100 per cent brown core. Excellent results were secured with McIntosh and other kinds of fruit.

I need scarcely call your attention to this work as pointing to a new method of commercial fruit transportation and storage.

---

[4] Poesch, G. H., and Laurie, Alex. 1935. The use of artificial light and reduction of the daylight period for flowering plants in the greenhouse. Ohio Agr. Exp. Sta. Bull. 559.

[5] Smock, R. M. 1938. The possibilities of gas storage in the United States. Refrig. Eng. Dec.

The Soil.—So extensive is the work with soils that I can only touch on a few trends.

Probably the most conspicuous to those of us who have been associated with horticulture for a good many years is that of soilless culture or hydroponics, as it has come to be known in some quarters. The very thought of growing crop plants to maturity without soil, without organic matter, is rank heresy. If I had not been in the midst of this work for the past few years I too would smile. How extensive it will become cannot be said, but the fact is that better quality flowers are being grown in a medium of gravel, cinders, or a similar inert material than in soil. In some cases the yields are also higher. For instance, 35 rose flowers are being produced per plant in gravel culture and 20 is the usual number in soil. Sweet peas average about 50 per cent more in gravel. Carnations produce no more cut flowers in gravel, but the blooms bring a premium on the market because of their quality. The same may be said of snapdragons, calendulas, stocks, lilies, daffodils, iris, and many annuals.

Among the vegetables, tomatoes are having a wider trial than others and there is some reason to suppose that they may be grown profitably without soil.

Among the advantages of this system of culture are better aeration, uniform moisture conditions, better control of soil-borne diseases, a better balanced condition of the nutrients, and control of the reaction of the medium.

Quoting an English reaction to soilless culture we see what is a somewhat facetious quip. "Of course, it is only right and proper in a commercial age to prove all things and hold fast to that which is cheap! Of course, it is very attractive for anyone with a love of the picturesque in prophecy to foretall the time when the soil of North America—and elsewhere—having slipped away in the sea or blown away into the air, the teeming millions of that and other continents will be sustained by the produce of the Great Lakes. The charm of Lake Superior and all the rest of them covered with crops! Waving fields of maize and wheat and all kinds of vegetables, all growing in and out of the water! We, for our part, however, would rather exercise our imagination in picturing how happier and healthier we should all be if research could discover how to make the earth more fertile."[6]

Turning more directly to the soil itself there are several factors that are being studied with profit and which have a much wider application, although not so spectacular as soilless culture.

Perhaps no phase of the soil factors has been so blandly discussed as the role of organic matter. I would not want to jostle this eternal verity from its throne in agricultural science, but it seems to me that some of our early teachings were pretty much fairy tales in the light of recent findings. That organic matter is built up as a bank account by the return to the soil of large quantities of manure or cover crops to be drawn on by the tree at some future time, has not stood the test of investigation. Referring to orchard soils in particular, it has been found that the growing of green crops which were turned into the soil has resulted in a net loss of total organic matter as compared to land which was left in sod or where the trees were mulched. At the Ohio Station we find, after 25 years, that the tilled land has 1.8 per cent organic matter as compared to 3 to 5 per cent under sod and mulch. Tillage of orchards on rolling land has been a fallacy which has resulted in untold loss of soil and ruination of its physical characteristics which many years of intelligent husbandry will not restore.

---

[6] Growing plants without soil. 1938. The Gard. Chron., Dec. 3.

Another result of recent studies has been the value of porosity or the movement of air and water through soil. The importance of this matter had been recognized for a long time, but not until the comprehensive work of Oskamp and other horticulturists at Cornell and elsewhere, had its real importance in the life and productiveness of an orchard been measured. The value of aeration in a soil has moved from its sacred place in the laboratory to a most vital position in agricultural practice. The curse of a compact soil, whether natural or brought about by injudicious culture, even in the name of a soil-building program, cannot be overestimated. I am here tempted to quote the familiar lines of Pope:

Where grows? Where grows it not? If vain our toil
We ought to blame the culture, not the soil.

We should not have expected Pope to know that the physical characteristics of a soil are of more importance than the system of culture for orchard purposes, but some who recently quote his lines with approval should know better.

With this we shall reluctantly leave an absorbing phase of horticultural work which is essentially ecology, and look briefly at some other areas of present day research.

PHYSIOLOGY

The importance of physiology in the minds of horticulturists can be measured by the number who take their basic training in this field and immediately engage in investigations in which this science provides most of the tools. To even catalogue these researches would be as impossible as undesirable in this connection. It seems even more difficult to determine just what does and what does not belong in this category.

Perhaps the investigation which stimulated more thinking and additional work than any other was that of Kraus and Kraybill on the relationship of nitrogen complexes and carbohydrates on the flowering of plants. In this the plantsman found a way of thinking about plants, something he could take hold of and manipulate to his purposes.

The discovery of deficiencies of so-called rare elements, such as boron, manganese, magnesium, copper, and zinc has opened a renewed interest in nutritional studies and some important progress has already been made.

Notable in the physiological studies is the development of apparatus for the study of carbon assimilation by leaves in the field and under controlled conditions, by Heinicke and his associates. This type of apparatus affords a means of conveniently determining the photosynthetic activity of leaves which have been sprayed with various materials and of leaves which are being attacked by insects and diseases, for determining the respiration rate of plants and their products at varying temperatures and with different amounts of light. Horticultural practice has already been influenced by these findings.

From the standpoint of an orchardist, the problem of securing higher color on fruits is of serious moment, especially since the use of nitrogen as a fertilizer tends to prevent the development of sufficient red color for highest market value. Chemical and experimental evidence shows clearly that a high foliage-fruit ratio favors high color provided the synthesis of nitrogen and carbohydrates into amino and protein complexes does not deplete carbohydrates. That is a ratio of 20 leaves per apple gives a lower sugar accumulation and a poorer development of color than 75 leaves. Expressed in orchard terms, the thinning of fruit results in higher color than occurs when a tree bears an excessive crop. These matters are within the hands of the orchardist but the situation is still not satisfactory. Very recently Dustman and Duncan have published results of spraying trees with soluble thiocyanates. The foliage is subjected to spray burn and to a chlorotic condition arising from the effect of the chemical on the green coloring matter of the plant, but in the fruit, the amount of red color occurring normally tends to be increased and the ground color tends to be reduced or replaced by varying shades of yellow and yellow green.[7]

Gardner, Marth, and Batjer[8] have demonstrated the value of certain plant growth substances (hormones) as capable of preventing abscission of various plant organs, including leaves, flowers, and fruits. This discovery has been put to practical use in delaying the preharvest drop of apples by spraying with dilute solutions of naphthaleneacetic acid. The commercial effect of increasing color of fruit as a result is yet to be worked out, but appears promising.

Other work with hormones and vitamins is in the limelight at the moment. The discoveries and the techniques used in the discoveries represent an epochal advance in the knowledge of plants and the forces that direct plant behavior. As might be expected, there are some exaggerations of what may be expected from these discoveries; on the other hand, some of the possibilities arising from these findings would be difficult to overstate. I refer particularly to the use of naphthaleneacetic acid in the production of seedless fruits of tomato, cucumber, and other fruits, not so much because the fruits are seedless, as because of the possibilities of getting a crop of fruit once the flowers are formed even though the pollen is not viable, as often happens in the greenhouse. I refer also to the use of acetylene and ethylene in controlling flower formation as demonstrated, for instance, with the pineapple in Hawaii and Australia where the entire harvesting period has been regulated.

The use of growth promoting substances in the rooting of cuttings seems to be over rated from a commercial standpoint, as does the use of Vitamin B_1 for plant growth.

---

[7] Dustman, R. B., and Duncan, I. J. 1940. Effects of certain thiocyanate sprays on foliage and fruit in apples. Plant Phys. 15: 343–348.

[8] By correspondence.

ULTIMATE OBJECTIVE IS QUALITY

With our typical stress on bigness and quantity, it is not strange that agricultural experiment stations have largely neglected quality except so far as there are dollar signs on it. A healthy, sturdy race of animals and men has not received first consideration. True, we have known that man and animal were dependent upon the products of the soil, have even recognized in a general way that "man was three parts water and one part concentrated grass," but to study the exact composition of these products from the standpoint of proper nutrition, not much was done, at least for man.

QUACKERY

I dislike to conclude with any remarks on quackery, but something akin to this is constantly in the picture and might as well be admitted. The fertile field for lurid colors, get-rich-quick schemes, for magic, wizardry, and the supernatural is probably a result of the large number of amateurs who engage in some sort of plant growing. The doctor, lawyer, and Indian Chief, alike, fall for the fabulous tales of an expert salesman; and, I regret to say, often the experienced greenhouse man, orchardist, and gardener are rivalled perhaps only by the golf greenskeeper as suckers.

Just recently I received a gallon can of Reico, which when sprayed on apple trees "will change the biennial bearing habit!" Other proprietary products now on the market, some with merit, others of doubtful value, are: transplantone, auxilin, vita-flor, hormodin, roottone, bloomlife, fruitone, and, of course, vitamin B_1. We must admit that if science comes, the commercial adventurer will not be far behind.

With all this, experiment stations and colleges still have ample work to do if the real merit of new products is to be determined and the innocent public protected.

The Great Naturalists Explore South America

It is unusual to run across a book on natural history written for the layman, which is both entertaining and authentic. The Great Naturalists Explore South America is a volume which conforms to the above standards. It consists of two parts. Part I gives an historical account of the naturalists who have traveled in South America. These include Humboldt, Boupland, Waterton, Darwin, Schomburgk, Edwards, Wallace, Bates, Spruce, Hudson, Pritchard, Beebe and Ditmars.

Part two consists of thirty chapters, devoted to descriptions of various animals peculiar to South America. There are forty excellent photographs of many of the animals discussed. Samples of interesting chapters are those dealing with the Vampire Bat, the Jaguar, Hummingbirds, Giant Boas, Electric Eels and Insects as Food. A five-page bibliography is included. We highly recommend this book, not only to the general reader, but also as a stimulating reference for Zoology students.—*D. C. Rife.*

The Great Naturalists Explore South America, by Paul Russel Cutright. 340 pp. New York, The MacMillan Co., 1940. $3.50.

Plant Galls

This book is a revision of the author's earlier work "Key to American Insect Galls," New York State Museum Bulletin, 200, 1917. About 2000 American galls are recorded, classified according to the plant families. Skeleton keys are used within the families, keys which are too incomplete to make ready identification possible. In the oak group, the reader is often abandoned to a list of 20 or more forms from which he must make a choice by reading descriptions.

A far more serious defect in this account of plant galls is the highly inadequate treatment of the biology of galls in the introductory chapter. No mention is made of Kuster's classification of gall types, though Kuster is the world authority on gall structure. The introduction of evolutionary concepts into the field of the higher galls has been totally neglected together with the theoretical application of the recent data on "organizers" which seems applicable in these studies. The most significant literature in these fields has been ignored.

It is unfortunate that the extensive bibliography of the earlier work could not have been included in this new edition, since the earlier bulletin has long been out of print. Only 18 references are given.

To any one interested in expending his acquaintance with animal induced galls, this book is about the only work to which he can turn to find a summary of the American forms. It, thus, should be represented in every biological library.

—*B. W. Wells.*

Plant Galls and Gall Makers. E. P. Felt. 364 pp. Comstock Publishing Company, Ithaca, New York. 1940.

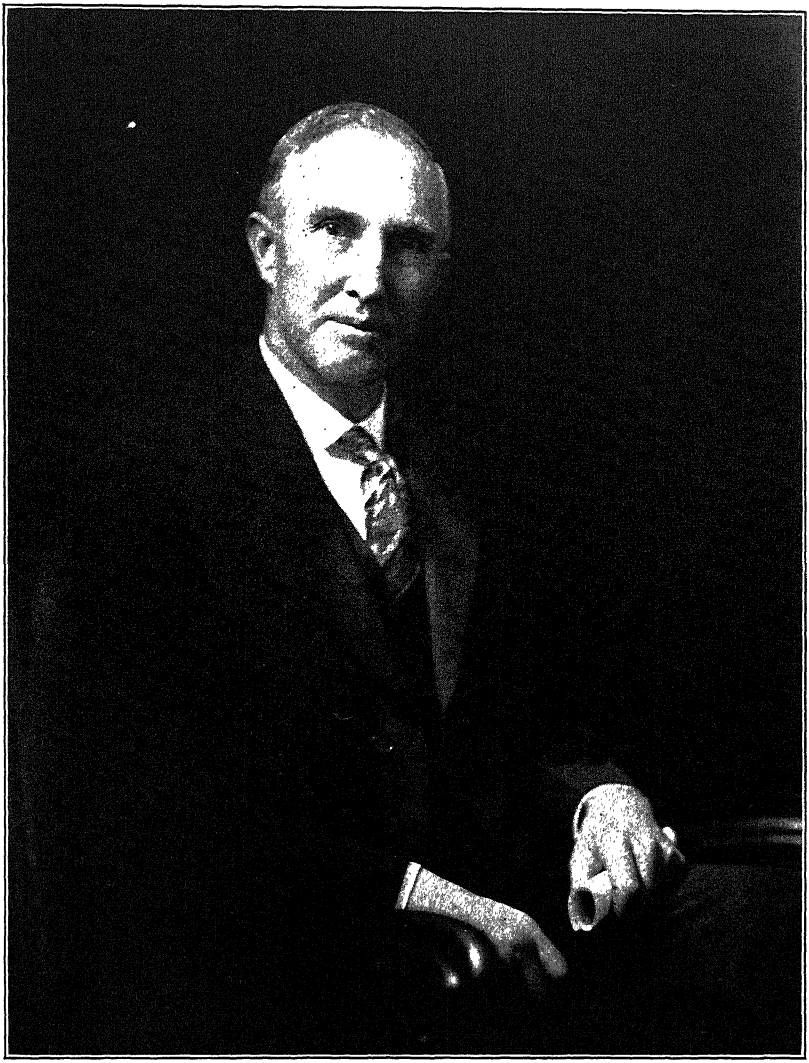
Is There Life on Other Worlds Than Ours?

Probably no other scientific question has been asked so often as has this one and probably no other question has received more unsatisfactory answers. In consequence, human imagination has soared and cheap fiction has prospered. The facts involved in the answer to the question are extraordinarily difficult to assemble in such form that a satisfactory answer is possible. No less a person than the Astronomer Royal of England now makes the effort and has done it exceptionally well. To be sure, the question is still unanswered as it must inevitably be for many years to come but here, at least, is a sober, understandable discussion of the elements and difficulties involved in the answer.

Mr. Jones discusses first the physical setting, then the conditions necessary for life as we know it, then goes on to a critical examination of the methods and limitations of investigation. This last discussion should be of particular interest to any one who wishes to understand why the question still remains unanswered. He also reviews the conditions that probably exist on the planets and comes to the general conclusion that on Mars life, if any, must be nearly done and on Venus it may be just beginning.

The book is well illustrated and interestingly written. There is an unfortunate error on page 37 in the chemical formula for sugar which has one atom of oxygen and one atom of hydrogen too many but this in no wise detracts from the value of the book. The reviewer heartily recommends this book to those who would like to see this problem as it stands today.—*C. E. H.*

Life on Other Worlds, by H. Spencer Jones. X*X*299 pp. with 17 plates. The Macmillan Company, New York. 1940.



JOHN HENRY SCHAFFNER

(1866—1939)

PROFESSOR JOHN HENRY SCHAFFNER

ADOLPH E. WALLER,
Ohio State University

BOYHOOD BACKGROUNDS

A small boy herding cattle in a vast expanse of prairie may not seem important. Doubtless many small boys have engaged in that not too difficult task. They have fought flies, chewed straws, and tried to amuse themselves, perhaps thoughtfully. Most of them have just sat by, waiting until it was supper time and the end of the day's labors. It was lonely to some, boring to others, perhaps exhausting their patience to know that they were prisoners tied to the cattle they were to guard. Most such boys would not think of themselves or of their jobs as offering much. Yet to a mind alive with curiosity such a contemplative life presents rich possibilities. If a landscape is somewhat bare, or at least simple, the individual objects take on a new significance. To a mind eager to question, each rock, each dip in the terrain, each stream requires exploring. With the passing of hours and months, the seasons take on a perspective. With growth of plants the lengthening stems and spray of bloom unfold mysteries that demand investigation. What wonder that the dense prairie sod with its complex and teeming life should hold a world for a small boy's mind!

Such a boyhood background in Professor Schaffner's life circumscribed the making of a great mind. He was born in Marion County, Ohio, near the Agosta prairie, with forests enclosing it, but his family moved early in his life to Clay County, Kansas. The prairie area he had left in Ohio was a mere patch of grassland, an island of grass in a landscape of trees. In Kansas it was different. Grasses and grassland forms reached across the horizon, only interrupted where pioneers had planted some trees near their homes or along streams where a narrow strip of woodland marked the water course. Grasses and cattle were his companions in the long hours he had to remain at watch. Why the flatness? Why the great stretches of sky? The work of the glaciers was still a new idea and probably not mentioned in his school. His parents were busy and perhaps had no time for such wonders. Yet these were the thoughts uppermost in the boy's mind. Geology became his first love in science, though he was far from any one who could talk much about it and had few books that could help him. But no lack of training or of encouragement from the circumstances in which he grew up could take away the desire to know all he could know of the grasslands around him. It would seem that the great expanses of prairie in which he was so small must have left him with a sense of his own obscurity. In later life his modesty never permitted his own great accomplishments to affect him. Like the small boy of the prairie, he was there, ready to speak or to act if any one was interested. But as with the small boy on the prairie, only a few came his way. He never learned to shout to attract the attention of others. The lonely life with the silent cattle also gave him a sense of his own competence. He was obliged to rely on himself. He formed the habits of self-dependence. He would act if he thought he was right. Having once made up his mind, nothing could move him to change his opinion as long as he thought he was right.

During the early days in Kansas the Schaffner family had to contend with the handicap of poverty. The house was the sod house familiar to many pioneer families of the grasslands. After working two years, the family had accumulated resources sufficient for the father to make a journey to Leavenworth, where a supply of lumber to build a more comfortable frame house was purchased. The lumber was paid for, but before the house was finished a raging prairie fire consumed it all. The Schaffner family, coming from Ohio, had not learned the precaution of plowing furrows to stop fires around the site selected for their wooden farm house. They were obliged to live for two more years in the sod house before again having enough money to buy lumber. This time the necessary strips of plowed land were prepared. After that, although there were a number of prairie fires, the house and the family were safe. In a reminiscent mood Professor Schaffner told this story to several members of the Botany Department staff as he recalled some of the exciting experiences of his boyhood.

Not only was the first Schaffner home of sod, but the earliest school house in the Clay Center area was a bank-sod house—a sort of basement structure. The walls and the roof cover were of sod. This was the school the elder sisters attended for several years. John spent most of his school years in a frame school house. It was a one-room building that served also as a social center, and in it were held the meetings of the debating society, the spelling matches, the Sunday School, and the box suppers. These were the pioneer's fun. There was one other—community singing. Schaffner was musically inclined. He was the only one in the school who could play the organ. He must have enjoyed this and talked about it for his parents at one time considered helping him to study music as a career.[1] This may have been in his college days, as Mr. Thomas A. Evans, Alumni Secretary of Baker University, Baldwin, Kansas, states that while Schaffner attended Baker he was in charge of the music at the Presbyterian Church and adds that Schaffner was gifted in playing the piano and organ and wrote poetry as a hobby.

The Schaffner family in many ways showed ingenuity and originality. The boys made mechanical wooden toys, and even a primitive *camera lucida*, which was set up for reflecting pictures on a screen. These amusements and visiting the neighbors occupied the long winter evenings. The parents were helpful in guiding their children toward instructive recreations.

Mr. D. C. Schaffner wrote: "By the time John started to high school it was taken for granted that he would go to college. Although the two older sisters taught school for a number of years after high school, they did not share this ambition for themselves but assisted

---

[1] This fact and much of the material at this point was kindly furnished by Mr. D. C. Schaffner, the younger brother, now Professor of Geology at Emporia College.

John and my younger sister and myself in college and graduate schools after each of us had taught in country schools. We formed a sort of teaching-and-going-to-college relay team." Of John, his brother wrote that "he was reticent but friendly. As far back as I can remember he never showed all of himself to anyone."

Science training was in a chaotic condition when young Schaffner at last was free to enter college; training in the classics was the only kind of education available in most of the colleges in the period from 1880 to 1900, and Schaffner's experiences were no different from those of many young men of his day. He was later to have a particular use for his knowledge of Greek and Latin in his scientific work. The classical tradition gave him a most careful training in the exact derivation of words, and his papers never contained new terms that were a polyglot mixture of Greek and Latin. His interest was captured by natural science, and it was geology that he first thought of pursuing.

As a further tribute to the Schaffner family it should be remarked that while the farm never was a source of wealth, it produced sufficient means and talents to be called remarkable. The younger sister is a noted attorney in Chicago; the younger brother, a geologist. The children were not bound down to the pioneer environment.

Probably the greatest inspiration toward research in botany for the boy John came from Dr. Charles Sylvester Parmenter, who was the teacher of biology and geology at Baker University. Dr. Parmenter was doubtless helpful also in securing for the young graduate of Baker University the job of teacher of natural sciences in the Methodist College at Mitchell, South Dakota. With all the delays of his high school and college years, John Schaffner was twenty-eight years old at the time he went to South Dakota. By then his path toward modern scientific study seemed to have become clear to him. After a year at the college at Mitchell he resigned his post to take up graduate studies at the University of Michigan. He remained for two years at Ann Arbor, where, under the guidance of Dr. Frederick C. Newcombe, he began intensive work in cytology.

He plunged at once into the most controversial subject of the moment, the question of cell organization at mitosis. His first paper dealt with the attraction spheres and centrosomes, present outside the cell nucleus, considered from the standpoint of their possible function during karyokinesis. This was a deep and difficult subject for a young research student to undertake. It was all the more ticklish from its didactic nature, since the most distinguished European cytologists were at that time at odds over their discoveries. Young John Schaffner had to master a reading knowledge of French and German to prepare his paper, since of the thirty-five references which he lists only two are in the English language.

THE YOUNG BOTANIST

While we know that Professor Schaffner was engaged in teaching the natural sciences at Mitchell College in South Dakota, we have been unable to trace his associates or to learn much of his development during the two years (1893–94) he remained in South Dakota. He published his first two papers after he had gone to Michigan. The one on the centrosomes was published in 1894, the other on the embryo sac of the water plaintain, *Alisma plantago*, in 1896. Both came out in the *Botanical Gazette*, which was at that time undergoing revolutionary improvements as a scientific journal. Dr. Coulter, its editor, had just been called to Chicago by President Harper. Dr. Spalding, head of the Department of Botany at Michigan, was on very friendly terms with Coulter, serving as an associate editor of the *Gazette*. Young Schaffner's papers were approved by both Spalding and Coulter, and appeared in the *Gazette* just as it was being revised and expanded. It is significant that young Schaffner came in with the first wave of the swelling tide of interest in botany in the United States, a tide, the level of which was greatly raised by the Chicago group of botanists.

It was at Chicago that the young scientist really began his intensive training in botany. He was attracted by the work of Dr. John M. Coulter and the *Gazette*, where his first paper had appeared. Coulter's success with the old *Botanical Gazette*, of which he had been editor while at Lake Forest College, had been marked. His co-editors, Charles Barnes and J. C. Arthur, were still loyal, but when the University of Chicago with its rich Rockefeller endowment, was behind it, it could make the necessary expansion. Dr. Coulter chose carefully when new associate editors were added—Atkinson of Cornell, Thaxter of Harvard, Spalding of Michigan, and Trelease of the Missouri Botanical garden. These were impressive names, and the quality of the materials Coulter proposed to publish made the new editors willing to lend their prestige.

By 1897, its success having been noted abroad, and Dr. Coulter having had a chance to visit Europe, foreign associate editors were added. The beginning of the great botanic center that was to make the University of Chicago famous for so many years was a reality. The new names made the editorial board of the *Gazette* a roster of botanists of first rank. They were De Candolle of Geneva, De Toni of Padua, Engler of Berlin, Guignard of Paris, Matsumura of Tokyo, Noll of Bonn, Marshall Ward of Cambridge, Warming of Copenhagen, Wittrock of the Academy of Sciences of Stockholm. The editorial staff in the main had no duties, of course, but their names were on the fly-leaf of the *Gazette*. Coulter and the staff of the University of Chicago and the graduate students in botany, who by this time numbered ten or more, contributed much of the materials. The graduate students were not unworthy to contribute to the *Gazette*. Most of them became distinguished professors of botany. In the famous paper on *Lilium*[2] Dr. Coulter names nine, of whom Otis W. Caldwell, Henry C. Cowles and T. C. Frye are perhaps the best known. Coulter did not include the names of Charles J. Chamberlain and John H. Schaffner in this list because Chamberlain and Schaffner independently produced the papers on the pollen sac and the macrospore nucleus of Lilium which were the features of this paper and to which Coulter's contribution was mainly the introduction and the organization of the materials to be studied. In spite of its being thus buried, Schaffner's studies were the important ones and the ones which today are referred to as the beginning of the evidence in plants for the studies in Mendelism and heredity. Schaffner's paper should have been published as a separate contribution. Everybody knows that now. For it was not just more details in cytology. It was the one idea that the botanists, especially the geneticists, needed.

---

[2] *Botanical Gazette*, Vol. 23, p. 412.

But Schaffner knew what he was doing. In his introductory sentence he said so. "Although a knowledge of the changes which take place in the reduction nuclei of plants and animals is of the utmost importance and will no doubt aid more than anything else in bringing about a correct interpretation of the facts of heredity, comparatively little has been done in this field, and the observations that have been reported disagree widely." There it was. He had done it, but it disagreed with earlier reports on chromosome behavior. Even Professor Coulter was afraid of it. The conclusion was too startling. And it was so unlike the conclusions of the European laboratories, which so authoritatively dominated the scene. Could it be that young Schaffner was right and some older famous heads were wrong? Let us quote some of the statements from the paper on *Lilium:*

> "Thus there is an actual transverse division of the chromosomes, the half of each original chromatin loop passing to opposite poles of the spindle. Each daughter nucleus, therefore, receives about as many chromatin granules as there were in the mother nucleus, and although there is no diminution in the number of chormatin granules, only half of the granules originally present in the mother nucleus are represented in each daughter nucleus. It will be seen that although the chromosomes are not all of the same size and length, yet if the chromatin band breaks at practically the middle point each daughter nucleus receives about the same number of chromatin granules; and since the chromatin granules are the same in number as in the mother nucleus it cannot be proper to speak of a reduction in the amount of chromatin, although only half of the original chromatin granules are represented. There is no reduction in number but a reduction of one-half in kind."

Whether Dr. Coulter approved or not, the paper had to be presented as a continuation of the morphological and cytological studies in progress, since a whole year's work was involved. But what would some of the foreign associate editors think of it? Was this young man too brash? He seemed quiet enough, but he could not be shaken in his conclusions, and the idea was startling. Now, forty-two years after it was published, we may say that Schaffner did not know he was supposed to agree with the European cytologists so he disagreed. We also may understand that since it was but a section of the planned program of *Lilium* studies it did not have the chance to attract the attention it deserved. It was true that it contained the history of the embryo sac, as the title might suggest. But it contained the startling observation of both a longitudinal and a transverse separation of chromosomes during meiotic processes. It was this type of division which was needed to account for Mendelian proportions in offspring that botanists were soon to be looking for. Schaffner was the first botanist to see it. Since the main point was not fully emphasized, the credit for this first observation was not entirely awarded to young Schaffner. But if he was disappointed in this, he had no time to fret. For the following year he was called to Ohio State and began the development of a career which was to last for forty-two years.

THE OHIO STATE UNIVERSITY BOTANICAL LABORATORY

The young assistant in the Department of Botany was chosen by Professor William A. Kellerman, who had himself been for a number of years at the University of Kansas before coming to Columbus. Dr. Kellerman was broadly trained and a ready lecturer, with a special interest in mycology. Mr. Schaffner was to assume responsibility for as many of the other phases of botanical science as he felt inclined. None of them was organized. The trails needed to be blazed by pioneers in every department. But few institutions would be fortunate enough to get young men who could blaze trails in so many different directions.

Before assuming his duties at Ohio State Mr. Schaffner returned to Kansas. This annual journey in the summers to Kansas became a fixed pattern in his life, and while no complete record exists, he probably missed few summer visits to his home. In 1897 we have a record for this summer that he visited Cloud County, Kansas, and devoted his studies to the salt marshes. He lists the plants inhabiting the marked vegetation zones around the margins of the marsh in a contribution to floristic ecology. Not only is it recognized today that this pioneer paper on the floras of our inland salt marshes is a valuable scientific record, but it is also Contribution Number One from the botanical laboratory of Ohio State University. This paper appeared in the April, 1898, number of the *Botanical Gazette.* Before this, even Dr. Kellerman, who founded the *Journal of Mycology* and was for many years a contributor to it, had not thought of the device of crediting the Ohio State University's support of his efforts. At that time, of course, Professor Kellerman was already a man of high professional reputation. He had influenced many students, both in Kansas and in Ohio, and played an important part in the development of the work in plant pathology, which was to rise so brilliantly in the Department of Agriculture just organized at Washington—where, later, his son was to become the head of the work in plant pathology. But the plan of crediting the institution which was paying his salary had apparently not occurred to him. His young assistant in botany was to give Ohio State its appropriate recognition. It is symbolic of the fact that Schaffner was entering whole heartedly into a plan of life that was to bring forth every effort in the development of his chosen field.

In 1892 Ohio State University had a new Dean of Agriculture. Professor Thomas F. Hunt, who had previously held the chair of Agriculture at State College, Pennsylvania, was called to the post to succeed Doctor Townshend, who had just retired in his seventy-seventh year. At the same time, the Department of Botany and Horticulture was divided. Professor W. R. Lazenby, who had long held the double title, was elected Professor of Horticulture. The title of Head of the Department of Botany was given to Professor William A. Kellerman. The building in which the classes in botany were conducted at that time is described in the catalogue of the university as follows:

> Botanical Hall was provided in 1883 by a state appropriation of fifteen thousand dollars. It is of brick and fifty feet long by forty feet wide. The whole structure is two stories in height. The general Botanical Laboratory occupies the second floor of Botanical Hall. It is 23x33 feet and is furnished with both movable and fixed tables. The latter are attached to the west and south walls near windows suitably shaded. Water, gas, and an evaporating hood are provided. The laboratory is equipped with compound microscopes of the Bausch-Lomb, the Leitz, and other patterns and accompanying each is a tray of tools and a case of reagents. There are more than fifty dissecting microscopes, also charts and several minor pieces of apparatus for experiments in vegetable physiology. Three smaller rooms are also provided as laboratories for special work as well as a dark room for photography. Other facilities for the illustration of the courses in botany and for practical training in the same are: a general herbarium including flowering plants, ferns, mosses, fungi, algae, a State Herbarium, a collection of fruits and seeds, valuable timbers, woods, grasses and various economic products of the vegetable kingdom; ornamental grounds and woodlands planted with a large variety of evergreen and deciduous trees and shrubs and a greenhouse with a fair collection of native and exotic plants.[3]

It should be said for the defense of this meager collection and the limited space that housed it, as we now may regard it, that it was representative of the conditions of the struggling state universities throughout the country. Only a few institutions were better equipped. In 1897, five years after Professor Kellerman had arrived, he listed in the department three herbaria, the general one, the state herbarium, and his own private herbarium of over 20,000 specimens. It had taken much effort and money to obtain these, and they were "deposited for use in the Botanical Dept."[4] In addition he had added a complete collection of native Ohio woods and a collection of native medicinal plants. But it should be said that botany as a science was beginning to emerge from the stage of concerning itself exclusively with description. It was turning to the dynamcis of plant life. Dr. Kellerman was one of the earliest to be aware that physiology needed to be studied and taught. He introduced a course in physiology and the text used was the best American volume of the day, written by Dr. Charles Barnes. Among other innovations this book included the term photosynthesis to replace the words "carbon assimilation" used by previous writers. In teaching the plant physiology Dr. Kellerman is said to have wandered far from his subject during a lecture hour. He would touch on main points but would leave to his assistants the job of quizzing. With the limited equipment, the amount of solid laboratory experimentation remains highly speculative. This may have developed ingenuity as well as put a severe tax on the patience of the assistant.

---

[3] Ohio State University Catalog 1893.

[4] Ohio State University Catalog 1897.

From Cope's *History of Ohio State University* is the statement that in 1898 Townshend Hall was completed.

> No pains or expense had been spared to make the building complete and satisfactory in every respect, and it was at that time the finest building of the kind in the country. It at once became an object of pride and admiration to the farmers of the state and did much toward awakening their interest in agricultural education and in reconciling them to the university.

Townshend Hall was formally dedicated by President Canfield, Dean Hunt, and the Secretary of the Board of Trustees, Mr. Cope. Townshend Hall was the first building of the Neil Avenue group. It flanked University Hall and Engineering. Across the oval were Botanical Hall and Orton Hall, which housed the university library as well as the geology department. From High Street there were only the President's Home, the Armory, and Hayes Hall. Except for residences of faculty members, the rest of the campus was without buildings. The woodlot at the northeast corner still contained remnants of the original beech forest. The campus served as a local flora collecting ground. Legend has it that the showy orchid inhabited the banks of the small brook that divided the campus. Perennially Professor Lazenby was asked to landscape the campus, but no funds except for tree-pruning seem to have been available. Two or three abortive attempts to start an arboretum or at least a garden were foredoomed to failure as the demands for buildings and roadways grew.

Botany, however, did not stem from the local situation. The department somehow became a center of learning, toward which students were attracted, and all Ohio was its collecting ground. Professor Kellerman was soon to collect farther afield. He began in 1902 his series of visits to Central America to study tropical fungi; his records of types new to science became so numerous that he established the *Journal of Mycology* to serve for himself and for others as a medium of publication of the discoveries. While he was away the main teaching duties fell upon Schaffner. The University Catalog lists fourteen courses offered during the school year. Some of these were for students in the Arts College and some for the medical and pharmacy students, since at that time the applications of botanical science to medicine and pharmacy were still regarded as more significant than the applications to agriculture. The field of plant physiology was still largely unorganized, though Schaffner taught plant physiology with the slight equipment that the laboratory afforded. The entire university enrollment for the year 1898–99 was 1,149 students. Some of the contemporary members of the faculty included: Edward Orton, Professor of Geology and State Geologist, who had "retired" from the presidency of the university in

1881 to go back to his beloved science; Sidney Norton, in chemistry; Samuel Derby, in Latin; William Rane Lazenby, in horticulture and forestry; George W. Knight, in history, political science, and constitutional law; David S. Kellicott, in zoology and entomology, and Albert M. Bleile, in anatomy and physiology. Some of the young men of the faculty included Wilbur Seibert, Francis Caldwell, Embury Hitchcock, William McPherson, Joseph Russel Taylor, Charles B. Morrey, Clair Dye, Thomas French, Charles Bruce, John Bownocker, Francis Landacre, William L. Evans, C. E. Sherman, Charles Foulk, and William L. Graves. John F. Cunningham was appointed Fellow and laboratory assistant in horticulture and forestry at this time.

The improvement of teaching and research was to become a single unified objective for Schaffner. The slim equipment was to be fully used. More would come. The collections necessary for a knowledge of the plant life of the state were to be increased. The various branches of botany were all to be explored. His papers reported studies in widely separated fields of the botanical sciences. In ecology appeared a paper on the origin of timber belts and on the spread of buffalo grass. These papers, forgotten now, contain subject matter again of interest to conservation programs. Their suggestive value was forty years ahead of their time. In plant physiology he wrote about self-pruning of trees, nutation of sunflowers, maximum height of plants. On the subject of weeds, already becoming prominent causes of loss to farmers and adding millions of dollars annually to operating costs of farms, he described the peculiar method of seed dispersal in tumbleweeds. To algology he contributed a paper in 1902 on Kansas desmids. These were pioneer works on little-known matters. They were serving to enlarge the mind of the young investigator and teacher and to prepare the way for those who would later specialize in these several fields. General botany was beginning to delve into the mazes of the fundamentals of plant life. If Professor Kellerman's lectures possessed breadth and were given in an interesting fashion, young Schaffner's work would attempt to plumb the depths and provide the lectures with new perspectives. He wanted to know how plants live, more than he cared about their existence as objects to be described. He was beginning the expansion of not only his own mental equipment, but his insight into the plant knigdom was also being utilized by the head of the department and others. There were too many courses offered by the small staff. The Catalog for 1902–1903 lists twenty-seven undergraduate and six graduate courses. The general herbarium had grown to 30,000 specimens, and Professor Kellerman's was still kept as a separate collection. Schaffner had found time to do all of this departmental work by unremitting effort, in which he did not spare himself. But he wanted more consolidation of effort

The Biological Club offered both a social outlet and a means of consolidating effort. It was later to become the parent of the Ohio Academy of Science and of at least two national honorary societies with biology as the major interest. At the November sixth meeting in 1899 Schaffner was elected president of the Biology Club. Taking his duties seriously he presented a paper at the following meeting December fourth entitled "The higher Phagophytes of Ohio." In December he went to the Cleveland meeting of the Academy and read two papers. He was elected a trustee and a member of the publication committee. At the meeting of June 4, 1900, of the Biology Club, he was elected Editor of the Ohio State University *Naturalist.* This became, with its name altered to the *Ohio Naturalist,* the official organ of publication for the Ohio Academy, and in 1916 had its name again changed to the *Ohio Journal of Science.* Professor Schaffner remained Editor through all its changes and expansions from 1900 to 1918. Professor Hine was associate editor and Professor Landacre business manager through a number of years.

From a diary in possession of Mrs. Schaffner the following entries are quoted:

"Nov. 28, 1901. Thanksgiving Day. We entertained Prof. W. C. Mills and family for dinner. In the afternoon I went with Mills to the O. S. U.–Kenyon football game. For supper we entertained John Bridwell, Frederick Tyler and Otto Jennings and brother."

"Nov. 29. Meeting of the Ohio Academy of Science. I read two papers entitled, "The self-pruning of woody plants" and "Plant ecology of Ohio; a general outline," the latter in connection with Mr. Tyler."

"Nov. 30. Meeting of the Academy. I read a short paper on "Observations on the origin of forest belts in Clay County, Kansas." In the afternoon I went to the meeting of the Columbus Horticultural Society." These entries along with the remarks of the preceding paragraphs indicate the zeal with which Assistant Professor Schaffner was executing his duties and carrying forward the enthusiasm for plant sciences he was developing at Ohio State.

The years 1906 to 1908 brought about many changes in the now well-established and growing Department of Botany at Ohio State. Professor Kellerman was devoting his attention more and more to his chosen life work. He was the editor and proprietor of the *Journal of Mycology* and in the habit of furnishing from his own pocket funds for publication if the subscription was not sufficient. He was preparing to add the *Mycological Bulletin* to his sheaf of duties. The herbaria were growing in importance and interest as many collections were added. Some of these were the collections of Central American fungi. The talk of a new building to replace the inadequate facilities for teaching and research had not brought about results, but they would come. Associate Professor Schaffner's salary was inadequately small, but he and Mrs. Schaffner both worked in the laboratory (on one salary), and he was beginning to save money for a trip abroad. Surely he deserved it. He had three score or so valuable papers published in different highly reputable journals, and the *Ohio Naturalist,* which he had edited from the beginning, was a definite success, largely through his efforts. There were graduate students, such as Gleason and York, making noteworthy progress and reputations for Ohio State. Gleason had gone to Illinois, York to the University of Texas, and Jennings to the Carnegie Museum at Pittsburgh. Schaffner seemed to have a way with the advanced students, especially when he was at work with them after class hours. He could talk to them freely then, and the new problems of a phylogenetic system of classification held their interest more than the routine classroom lectures. The roof leaked whenever it rained, the rooms were cold on chilly evenings, but physical discomforts were not important if the work in botany was going forward.

In 1906 the first Mrs. Schaffner, the beloved Mabel, died. In the March number of the *Botanical Gazette* appeared a notable paper on chromosome reduction in *Lilium tigrinum*. This paper re-established Schaffner's conclusions on the relation between chromosomes and Mendelism that he had foreshadowed, though not completely stated, in 1897. In this 1906 paper he acknowledged his grateful indebtedness to Mabel, who had prepared the 200 serial slides that his studies had required. She had helped him toward the recognition that his earlier work should have had. The July news items of the *Gazette* briefly recorded her death after a short illness. The notice mentioned her ability as a botanist of promise.

Mabel Brockett Schaffner had been the constant ally of her husband. In addition to the preparation of the slides she had studied the embryology of Shepherd's Purse and paved the way for Schaffner's publication of the first complete account of the embryology of a seed plant. Diary entries for May 26–30, 1906, indicate that on his return from the funeral in Kansas he had stayed at the home of his friends the Mills', had visited Professor and Mrs. McCall, and on the thirtieth contains the following: "worked at Mabel's drawings. They are nearly done, only some dotting in one. She was so anxious to get them done. They are on Bursa, Shepherd's Purse." Schaffner would bury his grief in his work. There were many problems he wanted to talk over with others. He would ask for a leave of absence and complete his work for his Doctorate. But where and how and who would carry on? Dr. Kellerman was interested in Central America and his trips put the teaching burdens on Schaffner. This was undoubtedly the most trying period—the most confused and confusing. It is not difficult to foresee what would happen to a shy, affectionate and lonely man.

At church he met Mrs. Mary Morton Sample and in April, 1907, became engaged to her. She was the mother by a former marriage of a daughter Jean and the courtship as recorded in diary entries indicate that Schaffner was reviving from his despair and even becoming gay. He went to the theatre to see Maude Adams in Peter Pan, took Miss Jean and Mary to the circus, attended church regularly, often twice in one day, and on May sixth, the first anniversary of Mabel's death, he and Mary shared with sympathetic tears the emotion roused by the Columbus Oratorio Society's performance of Haydn's "Creation."

Dr. Alfred Dachnowski—now Dr. A. P. Dachnowski-Stokes—was asked to fill Schaffner's place and especially to teach plant physiology during the leave for the school year 1907–1908. Dr. Kellerman would forego his contemplated fourth journey to Guatemala to study and collect tropical fungi. Schaffner was reappointed associate professor at a salary of $1600 a year. On this and with his savings and perhaps some income from his share of the Kansas farm he would go abroad. He could live on very little.

In a letter from Professor Daniel C. Schaffner there is the following statement: "When John went to Europe for graduate work his intention was to study at Berlin or at one of the other great German universities. However, he found no one there interested in or more than even incidentally conversant with the problems that were uppermost in his mind at that time. Consequently he spent several months in study in Paris and the greater part of his year in Zurich. At both of these places he found men interested in scientific research as he understood it and spent the months in an atmosphere of friendly and stimulating surroundings."

Comparison of these statements with the diary shows disagreement of several points. Clearly, reading the diary shows the confusion in John Schaffner's mind at this period in his life. He was emotionally down and up in rapid successsion. His work in the department was beginning to count with both his students and his colleagues. He had been editing the *Naturalist* for seven years and teaching botanical sciences for ten. He was forty-one years old and his experiences had matured him. After his return from travel and study abroad he would be capable of developing the fullness of his powers. Perhaps he could find the answers to his problems. He was distinctly turning toward problems of classification and had published four papers on the subject by this time. The great exponent of taxonomy in Germany was Engler, and it may be that Schaffner thought and spoke of systematic botany and the physogenetic systems he was beginning to develop. But he would not have found Engler receptive to views from an unknown American who probably would stir up discord in the views Engler was proposing. The most he could hope for from Engler would be to add one more monograph to the already extensive series. But this was not what was in Schaffner's mind. He was not finding fault with detail in an existing plan of study. He was trying to establish his own grasp on the plant kingdom as a whole. Anyway, there is no record in the diary of what his exact views might be. He did not, however, have Germany as a main objective. He sailed from Philadelphia to Liverpool, August 17, visited Oxford and Stratford. He spent a few days in London, staying at 21 Montague St., spent a few days in Paris and arrived in Geneva on September 8. He matriculated in the University of Zurich on October 14. Here he found a group of co-workers who accepted him and made him welcome. His diary once more records some of his experiences. He visited a Russian student affair, the Zurich Botanical Society, went to concerts in the Ton-balle, gave a talk in German at the Botanical Society, and entered fully into a delightful and lively gathering of intellectual comradeship. He only crossed Germany at the end of his stay on his way to Bremen to the ship for America. He had enjoyed his period of study in Zurich and made a warm friend and life long correspondent of Dr. Hans Schinz.

But a curious thing happened in Columbus. Kellerman had an opportunity to go away that was too fine to be resisted. The Board of Trustees of Ohio State University had caught the spirit of the investigations that were attracting Dr. Kellerman and some of his graduate students. Plant life was to be studied where it grew. The Ohio State University campus was to extend to Central America. The following quotation is from a notice that appeared in *Science*, August 23, 1907:

> A TROPICAL SCHOOL OF BOTANY
>
> Professor Doctor Kellerman of the Ohio State University, Columbus, Ohio, has planned a tropical school of botany for next winter which ought to attract the attention of some of our young men who are fitting themselves for their life work as teachers of botany. The session extends from December 19 to March 19, and will be held in Guatemala, Central America. The campus will be located at Zacapa, 100 miles from the coast, Los Amates, 40 miles inland, Izabal, on Lake Izabal, and perhaps also at Livingston, on the coast. Only a small number of young men will be accepted, and those who intend joining are advised to do so at the earliest day possible. The fee for three months, including traveling expenses, board and lodging, is $226.00. The project is one that should be of interest to botanists generally, as affording excellent opportunities for instruction along unusual botanical lines.

There was Kellerman's dream come true. He had been there on collecting trips three times previously. He saw in a land of smoking volcanos and great differences in altitude many opportunities to study a great range of plant life in the field. He would take care of the fungi and the others could collect specimens in other groups of the plant kingdom. So far as I am aware, this is the first time any university in the United States had authorized a School of Tropical Botany. Guatemala was a good choice. The railroad was started on the Atlantic side, and the United Fruit Company had its banana boats organized with excellent schedules for the journey across the Gulf of Mexico. Field work in geology and archeology could be fitted into botanical operations. Our dependence upon the tropics for a number of valuable and interesting products was just in its infancy. This was the time to go.

Looking at the exciting possibilities of the newly authorized School of Tropical Botany, Dr. Kellerman's dream seemed to have swept him off his feet. He seems now to have forgotten his own and Schaffner's teaching schedules. Perhaps Schaffner's plans for a doctorate degree could be adjusted later. Kudos meant little to Schaffner anyway. As Dr. Kellerman prepared to leave for Guatemala in December, 1907, perhaps some such thought flashed through his mind. There is no record that he wrote to Schaffner, nor any mention in the diary that Schaffner kept that he knew at this time that Dr. Kellerman was leaving. Certainly, Miss Detmers and Dr. Dachnowski could not manage the overloaded teaching program unaided. President W. O. Thompson sent for Schaffner. This confusion meant that Schaffner never obtained his doctorate. Also, the School of Tropical Botany had its first and last authorized journey.

Dr. Kellerman did not return. He died, presumably of malarial fever, March, 1908, and was buried in Zacapa. Three years later Professor Schaffner was appointed his successor as head of the department. On board the Kaiser Wilhelm der Grosse in Bremen, March 24, 1908, Schaffner received word of the death of Dr. Kellerman.

THE PRODUCTIVE YEARS

The growth of the University during the decade from 1910 to 1920 brought many changes. If the dedication of Townshend Hall in 1898 had helped "reconcile" the farmers, its expansion by 1910 and the outbreak of the war in 1914 put many unforeseen pressures upon faculty and student body. The department of botany under Professor Schaffner's chairmanship was provided with better space and facilities. In 1914, in Autumn, the present Botany and Zoology Building was opened for instruction. For the portion given over to botany there were some changes made that never suited Professor Schaffner. The west wings were each shortened about twenty feet and this curtailed the number of small research laboratories and instructors offices and scrapped plans for the elevator to the fourth floor where the enlarged herbarium was to be located. The building was given a high pitched roof and the spaces under the eaves were to contain dioramas, stilled life of animals and plants. Funds for these were never available, so the top floor was left largely unused during the first ten years the building was occupied. It was said at the time the building was opened in 1914 that the department would never be large enough to fill the available space. Within less than five years of the opening of classes in the new building the enrollment had reached a thousand. Many circumstances, including a new appreciation of the relation of botany to agriculture and horticulture as well as its pursuit as a basic science contributed to the enlarged demands placed by students on the staff. Professor Schaffner had built well. Not a building merely, but his views of botanical sciences were sound, as the contributions now so steadily flowing from his pen showed.

Again at a time when there were changes in the department and adjustments to be made, Professor Schaffner was occupied by personal emotional disturbances. Mary Morton Sample Schaffner died in September, 1914, and was buried in Washington, Pennsylvania. However, he attended the meeting of the American Association for the Advancement of Science in December with Professor W. G. Stover. At the meetings he served as a delegate to the Sigma Xi meeting and was elected to membership in the recently formed Botanical Society of America. In June, 1916, Professor Schaffner was married to Miss Cordelia Garber who became the mother of three children: Grace Odile, John, and James.

In 1918 the diary records "I resigned the headship of the Department of Botany and am now Professor of Botany doing mostly research work." This period from 1918 to the close of his life is the most productive. Here his researches and publications ripened to display the wisdom that those who knew him at this time learned to appreciate. His diary of that period no longer records in detail his publications or his strivings. He has begun to think about the effect of his writings on others—to sit back and plan with a greater sweep the advances of knowledge.

In the earlier years he may not have perceived that his efforts in consolidating the research in cytology and morphology would result in the life cycle studies being widely used by others. They were published in the *Ohio Naturalist* and his privately printed *Laboratory Outlines*.

From there they found their way to textbooks and have appeared in many places from 1915 on through the years. The same may be said of the studies that proceeded from the embryology of Sheperd's Purse for which he always gave the credit of great help to Mabel Schaffner. All of botany was moving toward a better understanding of plants. Schaffner was no longer alone in his work as he had been when he started. And in the more intensified studies that developed in the twenties respectful recognition of the pioneering work of the early days of Schaffner was not lacking.

Perhaps the most satisfactory evidence of the soundness of Schaffner's views came in the field of taxonomy. The series, "The Classification of Plants," was begun in 1905 and continued until 1922. The series entitled "Principles of Taxonomy" ran from 1924 to 1931. In both series a total of twenty-two papers appeared in the twenty-six years. His studies were based on an examination of the fundamental structures of plants. Surely this topic was not new to botanists, yet in Schaffner's hands it began to yield amazing results. He seemed to have an almost uncanny ability to rearrange plant series that clarified the many evolutionary problems. From an entirely unrelated field of studies, namely the study of serum reactions, European workers, notably Mez and his co-workers, of the University of Breslau, proposed an evolutionary sequence which in its main features agreed with the Schaffner system. In passing rather briefly over this noteworthy contribution, since it is too loaded with a vocabulary and technical details to expand the subject here, one may say that the difference between Schaffner's treatment and the older works on taxonomy is the application of the newer knowledge of plants to a phylogenetic system. His insight into the developments of plants enabled him to go forward rapidly where others had been misled by the mazes of detail. As a young graduate student at Chicago he had accepted the Engler system enthusiastically as a great improvement. Later he found that a new era was initiated by Bessey's use of the Bentham and Hooker system in 1894. In 1905 Schaffner published an outline of the classification of plants. In 1910, in the second edition of his *Laboratory Outlines*, he included a "tree" of the sixteen phyletic groups. In 1928 his ***Field Manual of the Flora of Ohio*** followed his phylogenetic treatment consistently.

His statement of the fundamentals may be found in the following quotation from his "Phylogenetic Taxonomy of Plants."[5]

> Botanical science has at last advanced far enough that a rather conclusive taxonomy can be established on a true evolutionary basis. But in order to discern the taxonomic system of plants properly, so as to avoid reasoning from the particular to the general, the botanist must certainly be familiar with the general characteristics of the whole plant kingdom, have a knowledge of life cycles, and also must be somewhat acquainted with paleontology and with ecological relations. The principle of organic change along definite lines will then become profoundly evident.

---

[5] Quart. Rev. Biol. Vol. 9, p. 131.

From the broad canvas on which he painted the parade of the whole plant kingdom through the ages, he looked on at the struggles of the newly rising and dynamic subject of genetics. After his discovery of the behavior of chromosomes in *Lilium* that contained the basis for Mendelian heredity, the account of the relations was published by Sutton in 1902. Schaffner did not return to the subject in a publication until 1905, when he used the title that should have been employed in the *Lilium* paper, "The Nature of the Reduction Division and Related Phenomena." There were five papers intervening, and in 1910 appeared the paper, delivered when he had been president of the Ohio Academy of Science at its 1909 meeting. Its title was, "The Nature and Development of Sex in Plants." This subject occupied him more or less consistently for the rest of his career. More than any other single subject, it showed how definitely he maintained his position in controversy if he thought he was right. It is of fundamental interest to biologists to see how from the beginning Schaffner's non-Mendelian view of sex was close to being the correct view. There were in all, twenty papers published on the nature and determination of sex. In these he was mainly upholding his position that sex is an expression of a physiological state and must be viewed as male, female, and neuter and that it cannot be determined by the chromosome structure as in ordinary shifting Mendelian phenomena. Instead, the chromosome and its transfer was to be regarded as a manifestation of some larger control in the set-up of the complicated life processes of the cell.

It was only a step, but an important one, to pass from such a concept of sexuality to the experimentation in sex reversals. Here he found the way to demonstrate in many different plants that sex reversals could occur either in the presence or absence of the extra chromosome. In all there were sixteen papers on the subject of the control and reversal of sex. At the beginning of the series of publications most biologists were indifferent or actually hostile to the concept of non-Mendelian sexual phenomena. Toward the end he had many followers who saw in the idea of ecological control of sex the explanations of their own specialized fields of investigation. As a result of his endeavors, I for one, feel that Schaffner's work has broadened the researches in genetics to admit some of the concepts of physiology and ecology hitherto lacking. Again looking for a short statement which may serve to summarize Schaffner's position, I take the liberty to quote his words:

> Any attempt to seek an explanation of sexuality and sex in terms of a balance of genes instead of a balance of physiological states would be beside the mark, since in all of these processes the balance of genes apparently remains the same.[6]

This paper ends with the suggestion that the study of the principles of reversal as worked out in plants may throw some light on human cases as they occur in medical history.

The eleventh paper in the series on determinate evolution contains perhaps Professor Schaffner's only quotation from the Bible, although he was throughout his life a constant church member. He had completed a series of extreme evolutionary trends in plants and compares some of these to the human brain. He ends the paragraph with the remark quoted from Psalms: "I am fearfully and wonderfully made." Here is for Schaffner an expression of the intense curiosity that animated his long and useful career.

---

[6] Bull. Torrey Bot. Club, Vol. 60, p. 96.

THE BIBLIOGRAPHY

The full citation of all of his papers follows. There is no other place, at present, where the entire list is to be found excepting this account. The Torrey Index has only about two-thirds of the full list.

It is hoped by this citation to show better than by the biographical sketch the full rounded activity of a truly great mind.

There were in all three hundred sixteen papers and books found in compiling the bibliography.[7] The following list presents them chronologically.

CHRONOLOGICAL CLASSIFICATION OF PAPERS

1894— 1
1895— 0
1896— 1
1897— 3
1898—10
1899—12
1900— 7
1901—13
1902—17
1903—22
1904— 8
1905—16
1906—11
1907— 3
1908— 6
1909—10
1910— 9
1911— 3
1912— 8
1913— 4
1914— 7
1915— 7
1916— 2
1917— 2

1918— 2
1919— 5
1920— 3
1921— 4
1922— 5
1923— 7
1924— 5
1925—10
1926—10
1927— 9
1928— 8
1929—10
1930— 7
1931— 8
1932— 5
1933— 6
1934— 5
1935— 5
1936— 4
1937— 5
1938— 7
1939— 4[8] (Unpublished)
——
316

The true significance of Professor Schaffner's contributions stands out if we attempt to classify the recorded writings. It is only then that the wide grasp of the Plant Kingdom which was his becomes evident. The groupings are as follows:

---

[7] Mr. Victor Greulach and Miss Ruth Krehl were of material aid in compiling the bibliography.

[8] Only the unpublished papers recorded in "Papers from the Dept. of Botany" by Prof. Schaffner are included here.

CLASSIFICATION OF PAPERS BY SUBJECT

I. SYSTEMATIC BOTANY (110)	
1. Taxonomy	
a. "Classification of Plants" series (1905–1922)	12
b. "Principles of Plant Taxonomy" series (1924–1931)	10
c. Studies of the genus *Equisetum* (1912–1938)	17
d. Miscellaneous (1912–1938)	6
2. Floristics	
a. Catalogs, supplements and records of Ohio Plants (1900–1939)	49
b. Keys and Manuals (Ohio and adjacent states) 1903–1931	13
c. Lists of lower plants (Mostly for Kansas) 1901–1910	3
II. EVOLUTION (15)	
1. "Studies in Determinate Evolution" series (1928–1938)	12
2. Miscellaneous (1898–1938)	3
III. ECOLOGY (26)	
1. Prairie vegetation (1899–1926)	3
2. Ohio vegetation (1902–1914)	3
3. Kansas vegetation (1898–1907–1938)	3
4. Equisetum ecology (1928–1934)	4
5. Miscellaneous (1899–1930)	13
IV. GENETICS (23)	
1. The nature and determination of sex (1910–1937)	20
2. Mutations (1906–1925)	3
V. CYTOLOGY (12)	
1. Studies related to genetics and reproduction (1896–1915)	8
2. Mitosis, etc. (1894–1908)	4
VI. PHYSIOLOGY (36)	
1. Growth (1898–1905)	7
2. Self-pruning (1901–1909)	5
3. Rejuvenation (1926–1928)	2
4. The control and reversal of sex (1919–1936)	16
5. Miscellaneous (1898–1932)	6
VII. MORPHOLOGY (38)	
1. Life cycles (1897–1906)	8
2. Floral structure and development (1897–1937)	4
3. Equisetum (1908–1938)	7
4. Miscellaneous (1901–1938)	19
VIII. LABORATORY PROCEDURE (41)	
1. Histological methods (1898–1900)	13
2. Other laboratory methods (1900–1902)	4
3. Laboratory outlines and manuals (1902–1915)	24
IX. MISCELLANEOUS (29)	
1. "News and Notes," etc. (1898–1915, 1935)	12
2. Terminology (1902–1906)	2
3. Pathology (of Equisetum) 1931	1
4. Zoology (1909–1923–1929)	3
5. Book reviews and reports	11[9]

---

[9] Not included in the total of 316.

LIST OF PAPERS ARRANGED IN THE GROUPS SHOWN ABOVE

I. Systematic Botany

1. Taxonomy

a. "Classification of Plants" series

The classification of plants, I. Ohio Nat. 5: 298–301. 1905.
The classification of plants, II. Ohio Nat. 6: 386–390. 1905.
The classification of plants, III. Ohio Nat. 6: 513–516, pl. 32. 1906.
The classification of plants, IV. Ohio Nat. 9: 446–455. 1909.
The classification of plants, V. Ohio Nat. 9: 489–494. 1909.
The classification of plants, VI. Ohio Nat. 11: 289–298, Fig. 1. 1911.
The classification of plants, VII. Ohio Nat. 12: 409–419. 1911.
The classification of plants, VIII. Ohio Nat. 13: 70–78. 1913.
The classification of plants, IX. Ohio Nat. 13: 101–130. 1913.
The classification of plants, X. Ohio Nat. 14: 198–203. 1914.
The classification of plants, XI. Ohio Nat. 14: 211–214. 1914.
The classification of plants, XII. Ohio Jour. Sci. 22: 129–139. 1922.

b. "Principles of Plant Taxonomy" series

Principles of plant taxonomy, I. Ohio Jour. Sci. 24: 146–160. 1924.
Principles of plant taxonomy, II. Ohio Jour. Sci. 25: 219–242, pl. 1. 1925.
Principles of plant taxonomy, III. Ohio Jour. Sci. 26: 294–311, Fig. 1, 2. 1926.
Principles of plant taxonomy, IV. Ohio Jour. Sci. 27: 249–261. 1927.
Principles of plant taxonomy, V. Ohio Jour. Sci. 28: 69–85. 1928.
Principles of plant taxonomy, VI. Ohio Jour. Sci. 29: 133–140. 1929.
Principles of plant taxonomy, VII. Ohio Jour. Sci. 29: 243–252. (illus.). 1929.
Principles of plant taxonomy, VIII. Ohio Jour. Sci. 29: 289–299, Fig. 1. 1929.
Principles of plant taxonomy. IX. Ohio Jour. Sci. 30: 261–272, Fig. 1–3. 1930.
Principles of plant taxonomy. X. Ohio Jour. Sci. 31: 77–96. 1931.

c. Equisetum

An undescribed *Equisetum* from Kansas. Ohio Nat. 13: 19–22. 1912.
North American species of *Equisetum* north of Mexico. Amer. Fern Jour. 17: 65–75. 1921.
How to distinguish the North American species of *Equisetum*. Amer. Fern Jour. 13: 33–40; 67–72. 1923.
Equisetum laevigatum and its near relatives. Amer. Fern Jour. 14: 41–46. 1924.
Main lines of evolution in *Equisetum*, I. Amer. Fern Jour. 15: 8–12. 1925.
Main lines of evolution in *Equisetum*, II. Amer. Fern Jour. 15: 35–39, pl. 3. 1925.
Equisetum variegatum Nelsoni, a good species. Amer. Fern Jour. 16: 45–48. 1926.
On the trail of *Equisetum* for four thousand miles. Amer. Fern Jour. 16: 81–92. 1926.
Diagnostic analysis and phylogenetic relationship of the main groups of *Equisetum*. Amer. Fern Jour. 20: 11–18. 1930.
Studies of *Equiseta* in European herbaria. Amer. Fern Jour. 21: 90–102, pl. 9. 1931.
Diagnostic key to the species of *Equisetum*. Amer. Fern Jour. 22: 69–75; 122–128. 1932.
Miscellaneous notes on *Equisetum*. Amer. Fern Jour. 23: 18–20. 1933.
Equisetum kansanum in Missouri. Amer. Fern Journ. 23: 64. 1933.
Kansas species of *Equisetum*. Amer. Fern Jour. 24: 36–38. 1934.
Distinguishing *Equiseta* with one or two rows of tubercles on the ridges. Amer. Fern Jour. 28: 121. 1938.
The distribution of the exclusively North American species of *Equisetum*. Amer. Fern Jour. 29: 45–47. 1939.

Chinese Species of *Equisetum*. Bull. Fan Inst. Biol., Bot. Ser. IX, No. 2, June 30, 1939. (With L. C. Li).

d. Miscellaneous

A revised taxonomy of the grasses. Ohio Nat. 12: 490–493. 1912.
Collecting horsetails along the way. Amer. Fern Jour. 18: 14–21. 1928.
Phytogenetic taxonomy of plants. Quart. Rev. Biol. 9: 129–160, Fig. 1, 2. 1934.
The proper name of the water horsetail. Amer. Fern Jour. 26: 91–94. 1936.
The importance of phylogenetic taxonomy in systematic botany. Ohio Jour. Sci. 38: 296–300. 1938.
The natural orders of the true mosses. Bryologist 41: 57–63. 1938.

2. Floristic

a. Catalogs, lists, etc. of Ohio plants.

Addition to the Ohio flora. Ohio Nat. 1: 16. 1900.
Ohio tumbleweeds. Ohio Nat. 1: 129. 1901.
Ohio tumbleweeds. Ohio Nat. 2: 174. 1902.
The flora of Little Chicken Island. Ohio Nat. 3: 331–332. 1902.
Ohio stations for Myriostoma. Jour. Mycol. 8: 173. 1902.
Poisonous and other injurious plants of Ohio. Ohio N.a. 4: 16–19; 32–35, 69–73. 1903.
Lycopodium prorphilum in Ohio. Ohio Nat. 5: 301. 1905.
Check list of Ohio trees. Ohio Nat. 6: 457–461. 1906.
Check list of Ohio shrubs. Ohio Nat. 8: 205–209. 1907.
Plants on the Ohio state list not represented in the state herbarium. Ohio Nat. 9: 413–415. 1908.
Six hundred plants of general distribution in Ohio. Proc. Ohio Acad. Sci. 5: 254–261. 1909.
Trees of Ohio and surrounding territory. Proc. Ohio Acad. Sci. 5: 73–191. 1909. (Special paper No. 15.)
The gymnosperms of Ohio. Ohio Nat. 10: 9–12. 1909.
New and rare Ohio plants. Ohio Nat. 10: 39. 1909.
The pteridophytes of Ohio. Proc. Ohio Acad. Sci. 5: 265–305. 1910. (illus.)
Additions to the flora of Cedar Point III (with M. E. Stickney and C. A. Davis). Ohio Nat. 10: 61–63. 1910.
A proposed list of plants to be excluded from the Ohio catalog. Ohio Nat. 10: 185–190. 1910.
Viola pedata in Ohio. Amer. Bot. 21: 143–144. 1915.
Filmy-fern native in Ohio. Amer. Fern Jour. 25: 17–18. 1935.
New and rare Ohio plants added to the state herbarium in 1910. Ohio Nat. 11: 246. 1910.
New and rare plants of Ohio. Ohio Nat. 12: 457. 1912.
New and rare plants added to the Ohio list in 1912. Ohio Nat. 13: 36. 1912.
Catalog of Ohio vascular plants. Ohio Biol. Surv. Bull. 2: 125–247. 1914.
New and rare plants added to the Ohio list in 1914. Ohio Nat. 15: 432. 1915.
Additions to the catalog of Ohio vascular plants for 1915. Ohio Jour. Sci. 16: 104. 1916.
The grasses of Ohio. Ohio Biol. Surv. Bull. 9: 256–329. 1917.
Additions to the catalog of Ohio vascular plants for 1916. Ohio Jour. Sci. 17: 132–136. 1917.
Additions to the catalog of Ohio vascular plants for 1917. Ohio Jour. Sci. 18: 99–100. 1918.
Additions to the catalog of Ohio vascular plants for 1918. Ohio Jour. Sci. 19: 293–298. 1919.
Additions to the catalog of Ohio vascular plants for 1919. Ohio Jour. Sci. 20: 131–136. 1920.
Additions to the catalog of Ohio vascular plants for 1920. Ohio Jour. Sci. 21: 128–135. 1921.
Additions to the catalog of Ohio vascular plants for 1921. Ohio Jour. Sci. 22: 91–94. 1922.

Additions to the catalog of Ohio vascular plants for 1922. Ohio Jour. Sci. 23: 107–114. 1923.
Additions to the catalog of Ohio vascular plants for 1923. Ohio Jour. Sci. 24: 107–116. 1924.
Additions to the catalog of Ohio vascular plants for 1924. Ohio Jour. Sci. 25: 130–138. 1925.
Additions to the catalog of Ohio vascular plants for 1925. Ohio Jour. Sci. 26: 169–182. 1926.
Additions to the catalog of Ohio vascular plants for 1926. Ohio Jour. Sci. 27: 95–101. 1927.
Additions to the catalog of Ohio vascular plants for 1927. Ohio Jour. Sci. 28: 205–214. 1928.
Additions to the catalog of Ohio vascular plants for 1928. Ohio Jour. Sci. 29: 81–92. 1929.
Additions to the catalog of Ohio vascular plants for 1929. Ohio Jour. Sci. 30: 98–108. 1930.
Additions to the catalog of Ohio vascular plants for 1930. Ohio Jour. Sci. 31: 299–307. 1931.
Revised catalog of Ohio vascular plants. Arranged according to the phyletic system of classification; with notes on the geographic distribution in the state, based mainly on specimens in the Ohio State Herbarium of the Ohio State University. Ohio Biol. Surv. Bull. 5: 89–215. 1932.
Additions to the catalog of Ohio vascular plants for 1931. Ohio Jour. Sci. 32: 158–161. 1932.
Additions to the revised catalog of Ohio vascular plants, I. Ohio Jour. Sci. 33: 288–294. 1933.
Additions to the revised catalog of Ohio vascular plants, II. Ohio Jour. Sci. 34: 165–174. 1934.
Additions to the revised catalog of Ohio vascular plants, III. Ohio Jour. Sci. 35: 297–303. 1935.
Additions to the revised catalog of Ohio vascular plants, IV. Ohio Jour. Sci. 36: 195–203. 1936.
Additions to the revised catalog of Ohio vascular plants, V. Ohio Jour. Sci. 37: 260–265. 1937.
Additions to the revised catalog of Ohio vascular plants, VI. Ohio Jour. Sci. 38: 211–216. 1938.

b. Keys and manuals

A key to the common families of seed plants. Pub. by the author. May 1, 1903.
Key to the genera of Ohio woody plants, based on leaf and twig characters. Ohio Nat. 5: 364–373. 1905.
Key to the genera of Ohio woody plants in the winter condition. Ohio Nat. 5: 277–286. 1905.
Key to the Ohio dogwoods in the winter condition. Ohio Nat. 6: 419. 1905.
Key to Ohio poplars in the winter condition. Ohio Nat. 5: 271. 1905.
Key to Ohio walnuts based on twig characters. Ohio Nat. 5: 307. 1905.
Spring flora. (W. A. Kellerman, H. A. Gleason and J. H. Schaffner) Columbus, Ohio. February 10, 1906.
A key to the families of seed plants in the central and northern states. Columbus, Ohio. 1912.
Key to the fruits of the genera of trees of the northern United States. Ohio Nat. 12: 506–512. 1912.
Field manual of trees. Columbus, Ohio. 1914.
A key to the families of seed plants in the central and northern states. 3rd rev. ed. Pub. by the author. 1915.
Field manual of the flora of Ohio. 1–638. Columbus, Ohio, R. G. Adams Co. 1928.
Manual of Ohio weeds (H. A. Runnels and J. H. Schaffner). Ohio Agric. Exp. Sta. Bull. 475. 1931.

c. Lists of lower plants

A list of Kansas Desmids. Ohio Nat. 1: 100–101. 1901.

Myxomycetes of Clay County, Kansas. Trans. Kan. Acad. Sci. 19: 204. 1905.

Edible and poisonous Mushrooms. Ohio State Univ. Agric. Coll. Ext. Bull. 5(9): 1–16. 1910.

II. Evolution

1. "Studies in determinate evolution" series.

The general course of evolution in the plant kingdom. Studies in determinate evolution I. Ohio Jour. Sci. 28: 277–291. 1928.

Orthogenetic series involving a diversity of morphological systems. Studies in determinate evolution II. Ohio Jour. Sci. 29: 45–60, Pl. 1–3. 1929.

Orthogenetic series resulting from a simple progressive movement. Studies in determinate evolution III. Ohio Jour. Sci. 30: 61–79, Pl. 1–7, Fig. 1. 1930.

Long-continued determinative orthogenetic series. Studies in determinate evolution IV. Ohio Jour. Sci. 31: 1–16. 1931.

Characteristic examples of accumulative progressive evolutionary movements. Studies in determinate evolution V. Ohio Jour. Sci. 31: 346–367. 1931.

Orthogenetic evolution of degree of divergence between carpel and foliage leaf. Studies in determinate evolution VI. Ohio Jour. Sci. 32: 367–378, Fig. 1–24. 1932.

Color in various structures and the so-called principle of selective adaptation. Studies in determinate evolution VII. Ohio Jour. Sci. 33: 182–191. 1933.

Duplicate evolution of peculiar perianth structures in the sedge family and the Composites. Studies in determinate evolution VIII. Ohio Jour. Sci. 34: 306–315, Fig. 1–14. 1934.

The tendency toward progression or perfection development in plant evolution. Studies in determinate evolution IX. Ohio Jour. Sci. 36: 80–101, Pl. 1, 2. 1936.

Examples of orthogenetic series in plants and animals. Studies in determinate evolution X. Ohio Jour. Sci. 37: 267–287, Fig. 1, 2. 1937.

Extraordinary developments at near the end of evolutionary series. Studies in determinate evolution XI. Ohio Jour. Sci. 39: 67–82. 1939.

The nature of the evolution of the fundamental potentialities in the plant kingdom. Studies in determinate evolution XII. Ohio Jour. Sci. 39: 327–347. 1939.

2. Miscellaneous

Atavism in certain Compositae. Jour. Col. Hort. Soc. 13: 127–129. 1898. Ohio State Univ. Agric. Student 5: 90–92.

Atavism in the Watermelon. Ohio Nat. 3: 370–371, Fig. 1. 1903.

Progression of sexual evolution in the plant kingdom. Ohio Jour. Sci. 22: 101–113. 1922.

III. Ecology

1. Prairie

The spreading of Buffalo Grass. Bot. Gaz. 27: 393–394. 1899.

The characteristic plants of a typical prairie. Ohio Nat. 13: 65–69. 1913. (Includes an enumeration of species of plants to be found.)

Observations on the grasslands of the central United States. Ohio State Univ. Studies. Contrib. in Bot. 178: 1–56. 1926. Fig. 1–12.

2. Ohio

Plant ecology of Ohio. Ann. Rept. Ohio State Acad. Sci. 10: 67–74. 1902. (With F. J. Tyler.)

Ecological study of Brush Lake. Proc. Ohio Acad. Sci. 4: 151–165, Fig. 1, 2. 1904. (Special paper No. 10.)

A preliminary survey of plant distribution in Ohio. Ohio Nat. 15: 409–418. 1914.

3. Kansas

Notes on the Salt Marsh plants of northern Kansas. Bot. Gaz. 25: 255–260. 1898.

Development of the forest belts in the northwestern part ot Clay County, Kansas. Trans. Kansas Acad. Sci. 20: 74–79. 1907.

Spreading of Opuntia in over grazed pastures in Kansas. Ecology 19: 348–350. 1938.

4. Equisetum

Rabbits eat *Equisetum praealtum*. Amer. Fern Jour. 18: 98–99. 1928.

Fluctuation in *Equisetum*. Amer. Fern Jour. 18: 69–79. 1928.

Geographic distribution of the species of *Equisetum* in relation to their phylogeny. Amer. Fern Jour. 20: 89–106. 1930.

Heredity and environment in relation to character expression with special reference to intermittent characters in *Eqyisetum*. Rev. Sudamer. Bot. 1: 8–17. 1934. (Revista Sudamerica de Botanica.)

5. Miscellaneous

Origin of timber belts. Bot. Gaz. 27: 392–393. 1899.

The maximum height of some common plants, I. Asa Grey Bull. 8: 19–20. 1899.

The maximum height of plants, II. Ohio Nat. 1: 39. 1901.

The maximum height of plants, III. Ohio Nat. 2: 1 2. 1901.

The maximum height of plants, IV. Ohio Nat. 3: 319. 1902.

The maximum height of plants, V.. Ohio Nat. 4: 23. 1903.

The struggle for life on a certain sandbar. Ohio Nat. 5: 302–303, Fig. 1. 1905.

An interesting *Botrychium* habitat. Ohio Nat. 10: 8–9. 1909.

Xerophytic adaptions of *Apocynum hypericifolium*. Ohio Nat. 10: 184–185, Fig. 1. 1910.

Ecological varieties as illustrated by *Salix interior*. Ohio Nat. 14: 255–256. 1914.

Effect of lightning on trunk of *Platanus occidentalis*. Bot. Gaz. 80: 226–227, Fig. 1. 1925.

A remarkable fern habitat. Amer. Fern Jour. 16: 79–81, Pl. 6. 1926.

The ecological determination of twisted hypocotyl and other peculiar expressions in hemp. Amer. Nat. 4: 367–379. 1930.

IV. Genetics

1. The Nature and Determination of Sex

The nature and development of sex in plants. Proc. Ohio Acad. Sci. 5: 327–350. 1910.

The expression of sexual dimorphism in heterosporous sporophytes. Ohio Jour. Sci. 18: 101–125. 1918.

The nature of the dioecious condition in *Morus alba* and *Salix amygdaloides*. Ohio Jour. Sci. 19: 409–416. 1919.

Dieciousness in *Thalictrum dasycaroum*. Ohio Jour. Sci. 20: 25–34. 1920.

The dioecious nature of buffalo grass. Bull. Torrey Bot. Club 47: 119–124. 1920.

The sexual nature of vegetative or dichotomous twins in *Arisaema*. Ohio Jour. Sci. 22: 149–154. 1922.

Observations on the sexual state of various plants. Ohio Jour. Sci. 23: 149–159. 1923.

The time of sex determination in plants. Ohio Jour. Sci. 23: 225–240. 1923.

Expression of the sexual state in *Sagittaria latifolia*. Bull. Torrey Bot. Club 51: 103–112. 1924.

Sex determination and sex differentiation in the higher plants. Amer. Nat. 59: 115–127. 1925.

Synapsis considered as a sexual phenomenon. Ohio Jour. Sci. 25: 183–189. 1925.

Questionnaire on certain facts bearing on the theory of sexuality and chromosome constitution. Science II 63: 384–385. 1926.

The nature and cause of secondary sexual states with special reference to *Typha*. Bull. Torrey Bot. Club 53: 189–208. 1926.

Sex-limited characters in heterosporous sporophytes. Ohio Jour. Sci. 27: 19–24. 1927.

Sex-limited characters and allosome linked heredity. Ohio Jour. Sci. 27: 105–126. 1927.

Sex and sex-determinations in the light of observations and experiments on dioecious plants. Amer. Nat. 61: 319–332, Fig. 1. 1927.

Extraordinary sexual phenomena in plants. Bull. Torrey Bot. Club 54: 619–629. 1927.

Heredity and sex. Ohio Jour. Sci. 29: 1–26. 1929.

Observations and experiments on sex in plants. Bull. Torrey Bot. Club 62: 387–400, Fig. 1. 1935.

Stability and unstability of sexual conditions in *Morus alba*. Jour. Heredity 28: 426–427. 1937.

2. Mutation, etc.

A successful mutant of *Verbena* without external isolation. Ohio Nat. 7: 31–34. 1906.

A remarkable bud sport of *Pandanus*. Jour. Heredity 10: 376–378, Fig. 14. 1919.

What happened to the *Pandanus* bud sport? Jour. Heredity 16: 62. 1925.

V. CYTOLOGY

1. Studies related to reproduction and genetics.

The embryo-sac of *Alisma plantago*. Bot. Gaz. 21: 123–132, Pl. 9–10. 1896.

The division of the megaspore of Erythronium. Science II 10: 565–566. 1899.

The nature of the reduction division and related phenomena. Ohio Nat. 5: 331–340. 1905.

Chromosome reduction in the microsporocytes of *Lilium tigrinum*. Bot. Gaz. 41: 183–191, Pl. 12, 13. 1906.

Synapsis and synizesis. Ohio Nat. 7: 41–48, Pl. 4. 1907.

On the origin of polar conjugation in the angiosperms. Ohio Nat. 8: 255–258. 1908.

The reduction division in the microsporocytes of *Agave virginica*. Bot. Gaz. 47: 198–214, Pl. 12–14. 1909.

The chromosome mechanism as a basis for Mendelian phenomena. Ohio Nat. 15: 509–518, Fig. 1. 1915.

2. Mitosis, etc.

The nature and distribution of attraction-spheres and centrosomes in vegetable cells. Bot. Gaz. 19: 445–459, Pl. 33. 1894.

Karyokinesis in the root tips of *Allium cepa*. Bot. Gaz. 26: 225–238, Pl. 21, 22. 1898.

Artificial production of the sickle stage of the nucleus. Jour. App. Micros. 2: 321–322. 1899.

The centrosomes of *Marchantia polymorpha*. Ohio Nat. 9: 383–388, Pl. 21. 1908.

VI. PHYSIOLOGICAL STUDIES

1. Growth

Observations on the mutation of *Helianthus annuus*. Bot. Gaz. 25: 395–403. 1898. (Illus.)

The mutation of Helianthus. Bot. Gaz. 29: 196–200. 1900 (Illus).

Notes on the nutation of plants. Ohio Nat. 4: 30–32, Fig. 1, 2. 1903.

Leaf expansion of trees and shrubs in 1904. Ohio Nat. 5: 210–213. 1904.

Six nutating plants. Ohio Nat. 5: 214–215. 1904.

Leaf expansion of trees and shrubs. Ohio Nat. 5: 363. 1905.

Artificial parthenocarpy. Jour. Heredity 26: 261–262, Fig. 1. 1935.

2. Self-pruning

Notes on the self-pruning of trees. Ohi. Nat. 1: 29–32, Fig. 1–4. 1901. (With F. J. Tyler.)
The self-pruning of woody plants. Ohio Nat. 2: 171–174, Fig. 1. 1902.
Observations on self-pruning and the formation of cleavage-planes. Ohio Nat. 3: 327–330. 1902.
Additional observations on self-pruning. Ohio Nat. 6: 450–451. 1906.
How plants shed their branches. Ohio State Univ. Agric. Coll. Ext. Bull. 5(4): 4–10. 1909.

3. Rejuvenation

The change of opposite to alternative phyllotaxy and repeated rejuvenations in hemp by means of changed photoperiodicity. Ecology 7: 315–325, Fig. 1. 1926.
Further experiments in repeated rejuvenations in hemp and their bearing on the general problem of sex. Amer. Jour. Bot. 15: 77–85, Fig. 1. 1928.

4. The control and reversal of sex.

Complete reversal of sex in hemp. Science II 50: 311–312. 1919.
Influence of environment on sexual expression in hemp. Bot. Gaz. 71: 197–219, Pl. 11, Fig. 1. 1921.
Reversal of the sexual state in certain types of monecious inflorescences. Ohio Jour. Sci. 21: 185–198, Pl. 1–2. 1921.
Control of the sexual state in *Arisaema triphyllum* and *Arisaema dracontium.* Amer. Jour. Bot. 9: 72–78. 1922.
Sex reversal in the Japanese hop. Bull. Torrey Bot. Club 50: 73–79, Pl. 23. 1923.
The influence of relative length of daylight on the reversal of sex in hemp. Ecology 4: 323–334. 1923.
Experiments with various plants to produce change of sex in the individual. Bull. Torrey Bot. Club 52: 35–47. 1925.
The influence of the substratum on the percentage of sex reversal in winter-grown hemp. Ohio Jour. Sci. 25: 172–176. 1925.
Siamese twins of *Arisaema triphyllum* of opposite sex experimentally induced. Ohio Jour. Sci. 26: 276–280, Fig. 1. 1926.
Control of sex reversal in the tassel of Indian corn. Bot. Gaz. 84: 440–449, Fig. 1–3. 1927.
Fluctuation of the point of sex reversal in *Sagittaria latifolia.* Amer. Jour. Bot. 16: 191–195. 1929.
Progeny resulting from self-pollination of staminate plant of *Morus alba* showing sex reversal. Bot. Gaz. 87: 653–659. 1929.
Sex reversal and the experimental production of neutral tassels in *Zea mays.* Bot. Gaz. 90: 279–298, Fig. 1–4. 1930.
The fluctuation curve of sex reversal in staminate hemp plants induced by photoperiodicity. Amer. Jour. Bot. 18: 424–430, Fig. 1. 1931.
The production of vestigial and sterile sex-organs through sex-reversal and neutral sexual states. Bull. Torrey Bot. Club 60: 89–97. 1933.
Offspring of a self-pollinated reversed carpellate plant of *Morus alba.* Bot. Gaz. 98: 425–428. 1936.

5. Miscellaneous

Demonstration of the flow of latex in the stipules of *Ficus elastica.* Jour. App. Micros. 1: 201. 1898.
Plants with nodding tips. Ohio Nat. 5: 267, Fig. 1. 1905.
Nodding of the terminal heads of *Silphium laciniatum.* Ohio Nat. 7: 39. 1906.
The diurnal nodding of the wild carrot and other plants. Ohio Nat. 12: 474–475. 1912.
The sprouting of the two seeds of the cocklebur. Ohio Nat. 14: 216–217. 1914.
Propagation of *Equisetum* from sterile aerial shoots. Bull. Torrey Bot. Club 58: 531–535. 1932.

VII. MORPHOLOGY

1. Life cycles

Contributions to the life-history of *Sagittaria variabilis*. Bot. Gaz. 23: 252–273, Pl. 20–26. 1897.

Contribution to the life history of *Lilium philadelphicum*. The division of the macrospore nucleus. Bot. Gaz. 23: 430–452, Pls. 37–39. 1897.

A contribution to the life history and cytology of *Erythronium*. Bot. Gaz. 31: 369–387, Pl. 4–9. 1901.

The life cycle of an Angiosperm. Gamophyllous 1: 57–59, 65–67. 1901.

The life cycle of a Gymnosperm. Gamophyllous 3: 17–21, Pl. I. 1903.

The life cycle of a heterosporous pteridophyte. Ohio Nat. 5: 255-260. Fig. 1. 1905.

Sexual and non-sexual generations. Ohio Nat. 6: 473. 1906.

The life cycle of a homosporous pteridophyte. Ohio Nat. 6: 483–488, Fig. 1. 1906.

2. Floral structure and development

The development of the stamens and carpels of *Typha latifolia*. Bot. Gaz. 24: 93–102, Pl. 4–6. 1897.

A general system of floral diagrams. Ohio Jour. Sci. 16: 360–364, Pl. 27. 1916.

The flowers of the golden-club. Amer. Bot. 43: 99–103. 1937. (Illus.)

The fundamental nature of the flower. Bull. Torrey Bot. Club 64: 569–582, Pl. 12, 13. 1937.

3. Equisetum

The air cavities of *Equisetum* as water reservoirs. Ohio Nat. 9: 393–394. 1908.

Spiral shoots of *Equisetum*. Amer. Fern Jour. 17: 43–46, Pl. 2. 1927.

The occurrence of three and four-angled branches in *Equisetum arvanse*. Amer. Fern Jour. 19: 24–26. 1929.

The flowers of *Equisetum*. Amer. Fern Jour. 19: 77–82. 1929; 119–126, Pl. 8, 9. 1930.

Six interesting characters of sporadic occurrence in *Equisetum*. Amer. Fern Jour. 23: 83–90, Pl. 4. 1933.

Random observations on *Equisetum*. Amer. Fern Jour. 25: 6–11. 1935.

Root hairs of *Equisetum praealtum* Raf. Amer. Fern Jour. 28: 122. 1938.

4. Miscellaneous

Petioles of the cottonwood. Ohio Nat. 1: 28. 1901.

Perennial tumbleweeds. Ohio Nat. 1: 67–68. 1901.

Ohio plants with contractile roots. Ohio Nat. 3: 410. 1903.

Deciduous leaves. Ohio Nat. 4: 163–166. 1904.

Some morphological peculiarities of the Nymphalaceae and Helobiae. Ohio Nat. 4: 83–92. 1904.

Ohio plants with extra floral nectaries and other glands. Ohio Nat. 4: 103–106. 1904.

The jacket layer in Sassafras. Ohio Nat. 4: 192–193, Fig. 1. 1904.

Twigs of the common hackberry. Ohio Nat. 5: 215–216. 1904.

Mat plants. Ohio Nat. 5: 265–266. 1905.

Ohio plants with extra floral nectaries and other glands. Ohio Nat. 6: 399. 1906.

Winter buds of Ohio trees and shrubs. Ohio Nat. 6: 505–507. 1906.

Leaf markings of certain Ohio plants. Ohio Nat. 11: 243–245. 1910.

Leaf markings of plants. Amer. Bot. 17: 5–10. 1911.

The North American lycopods without terminal cones. Ohio Nat. 12: 497–499, Fig. 1–4. 1912.

Peculiar varieties of *Amaranthus retroflexus*. Ohio Nat. 15: 469–471, Fig. 1. 1915.

Unusual dichotomous branching in *Vernonia*. Ohio Jour. Sci. 19: 487–490, Fig. 1. 1919.

Dichotomous branching in *Equisetum*. Amer. Fern Jour. 14: 56–57. 1924.

Ginkgo, a flowerless seed plant. Amer. Jour. Bot. 14: 126–128, Fig. 1. 1927.

Spiral systems in the vascular plants. Bull. Torrey Bot. Club 65: 507–529. 1938.

VIII. LABORATORY PROCEDURE

1. Histological methods

An improved paraffin embedding dish. Jour. App. Micros. 1: 11. 1898.

A permanent stain for starch. Jour. App. Micros. 1: 181. 1898.

Imbedding spores and pollen grains. Jour. App. Micros. 1: 202. 1898.

A suggestion to slide box makers. Jour. App. Micros. 1: 224. 1898.

General methods in botanical microtechnique. I. Jour. App. Micros. 2: 225–227 (No. 1). 1899.

General methods in botanical microtechnique. II. Jour. App. Micros. 2: 257–260 (No. 2). 1899.

A convenient washing apparatus‘ Jour. App. Micros. 2: 226. 1899.

A good killing fluid. Jour. App. Micros. 2: 465. 1899.

A design for a convenient staining dish. Jour. App. Micros. 2: 559. 1899.

Note on staining stems, roots and rhizomes. Jour. App. Micros. 2: 284. 1899.

Note on permanent mounts of pollen. Jour. App. Micros. 2: 341. 1899.

A differential stain for cell structures. Jour. App. Micros. 3: 799. 1900.

Mounting in glycerine. Jour. App. Micros. 3: 961. 1900.

2. Other laboratory methods

The laboratory notebooks. Jour. App. Micros. 3: 887–888. 1900.

Note on microscope cover. Jour. App. Micros. 3: 888. 1900.

Collecting and preserving microscopic plants. Ohio Nat. 1: 16. 1901.

Oculars for general laboratory work. Jour. App. Micros. 5: 1646. 1902.

3. Laboratory outlines

Laboratory outlines, I. Jour. App. Micros. 5: 1639–1645 1902.
Laboratory outlines, II. Jour. App. Micros. 5: 1698–1700. 1902.
Laboratory outlines, III. Jour. App. Micros. 5: 1798–1799. 1902.
Laboratory outlines, IV. Jour. App. Micros. 5: 1852–1854. 1902.
Laboratory outlines, V. Jour. App. Micros. 5: 1896–1897. 1902.
Laboratory outlines, VI. Jour. App. Micros. 5: 1934–1935. 1902.
Laboratory outlines, VII. Jour. App. Micros. 5: 2013–2014. 1902.
Laboratory outlines, VIII. Jour. App. Micros. 5: 2055–2056. 1902.
Laboratory outlines, IX. Jour. App. Micros. 5: 2093–2094. 1902.
Laboratory outlines, X. Jour. App. Micros. 6: 2134–2135. 1903.
Laboratory outlines, XI. Jour. App. Micros. 6: 2185–2186. 1903.
Laboratory outlines, XII. Jour. App. Micros. 6: 2237–2239. 1903.
Laboratory outlines, XIII. Jour. App. Micros. 6: 2275–2277. 1903.
Laboratory outlines, XIV. Jour. App. Micros. 6: 2330–2332. 1903.
Laboratory outlines, XV. Jour. App. Micros. 6: 2387–2388. 1903.
Laboratory outlines, XVI. Jour. App. Micros. 6: 2471-2474. 1903.
Laboratory outlines, XVII. Jour. App. Micros. 6: 2517–2522. 1903.
Laboratory outlines, XVIII. Jour. App. Micros. 6: 2571–2576. 1903.
Laboratory outlines, XIX. Jour. App. Micros. 6: 2611–2627. 1903.
Laboratory outlines, XX. Jour. App. Micros. 6: 2689–2700. 1903.

Laboratory outlines for general botany. 93 pp. Columbus, Ohio. 1905.

Laboratory outlines for general botany. 2d ed. 101 pp. Pub. by the author. 1908.

Laboratory outlines for general botany. 3rd ed. 125 pp., Pl. 1, 2; Fig. 1–17. Columbus, Ohio. 1913.

Laboratory outlines for general botany. 4th ed. 128 pp. Pub. by the author. 1915.

IX. Miscellaneous

1. "News and Notes," etc.

The Botanical Department of Ohio State University. Jour. App. Micros. 1: 188. 1898.
Announcement. Ohio Nat. 1: 1–2. 1900.
News and notes. Ohio Nat. 1: 48. 1901.
News and notes. Ohio Nat. 1: 106. 1901.
Notice of A. J. Pieters' work on plants of western Lake Erie. Ohio Nat. 2: 166. 1901.
News and notes. Ohio Nat. 4: 23–24. 1903.
News and notes. Ohio Nat. 4: 47. 1903.
News and notes. Ohio Nat. 4: 47. 1903.
News and notes. Ohio Nat. 4: 74. 1903.
News and notes. Ohio Nat. 4: 148. 1903.
News and notes. Ohio Nat. 9: 394–395. 1908.
A new laboratory guide for High School botany. Ohio Nat. 10: 40. 1910.
Introductory, "Ohio Jour. Sci." Ohio Jour. Sci. 16: 1–2. 1915.

2. Terminology

On the use of some common botanical terms. Ohio Nat. 2: 215–218. 1902.
Terminology of organs in various conditions of development. Ohio Nat. 6: 541–544. 1906.

3. Pathology

Injurious fungus parasite of *Equisetum*. Amer. Fern Jour. 21: 75. 1931.

4. Zoology

Chromosome difference in *Ascaris megalocephala*. Ohio Nat. 9: 506–508. 1909.
A duck with webless feet. Ohio Jour. Sci. 23: 207–208. 1923.
Extension of the natural range of two mammals in Clay County, Kansas. Trans. Kans. Acad. Sci. 31: 61–62. 1929.

If we attempt to cast into form some of the outstanding achievements indicated by the long list of writings perhaps the following may serve:

1. Contains the first report for Botanical Science of the behavior of the chromosomes in the process of meiosis. This cytological advance embodied in the paper on *Lilium* in 1897 antedated by two or three years the rediscovery of Mendel's work.

2. The diagrammatic representation of life cycles now extensively used in text books first appeared in the published works of Professor Schaffner.

3. These papers contain the first complete series of illustrations of the embryology of a seed plant. As in the above case, these illustrations have been widely used in text books, or have been the suggestion for further research.

4. From morphological studies there developed a system of plant taxonomy differing from the widely used European systems but finding substantiation and agreement in the testing of natural relationships of serological methods.

5. Constantly upheld the stand that sex inheritance cannot be regarded for most organisms in the same light as simple Mendelian traits. In such organisms as possess a special chromosome associated with sex and in which sex reversal has not yet been shown to occur, Professor Schaffner took the position that sex is part of a physiological reaction system distinct from the Mendelian system.

6. Demonstrated experimentally principles of sex reversal. By the use of physiological and ecological methods Professor Schaffner was able to show that sex expression could be controlled. Vegetative divisions or "Siamese twins" cuold be developed as male or as female, in response to environmental conditions.

7. Through the examination of neutral states and the existence of inter-sexes in a wide range of forms in the plant kingdom, showed that only where the time of sex determination coincided with the reduction processes could sex expression appear to resemble superficially ordinary Mendelian expression.

8. Upheld the principle that all Mendelian inheritance is superimposed upon the fundamental inheritance in organisms.

9. Demonstrated the major evolutionary trends in the plant kingdom by an original system of comparative study.

10. Outlined the evolution of potentialities in the plant kingdom.

11. Became internationally recognized as an authority on the genus *Equisetum* and contributed numerous revisions to the interpretation of this group.

12. Since the subject of *Equisetum*, and the works on reproduction and sex reversal are of such paramount interest, a brief additional classification of these items is appended.

SPECIAL CLASSIFICATIONS:

Equisetum.

1. Taxonomy	15
2. Ecology	4
3. Physiology	1
4. Morphology	7
5. Pathology	1
	28

Sex and Reproduction.

1. The nature and determination of sex	20
2. The control and reversal of sex	16
3. Life cycles	8
4. Floral structure and development	4
5. Cytological studies	8
6. Nutations	3
	59

MEMORABILIA

The passing of a great mind that has been an inspiration for others always brings recollections. We have shared a personality, we have momentarily apprehended a vision that is not ordinary. We build into a great picture only if we do not try to pretend that the subject of our thought was without weakness. From a number of letters from which the following statements are quoted the reader will find some of those endearing human traits not always perceptible in reviewing the accomplishments of a creative worker. I wish here to express my appreciation to the authors of the letters written to me, and to thank Mrs. Schaffner for the first one quoted. Not all letters received have been used, since the same thought was expressed by different writers.

WILLARD M. KIPLINGER, Washington, D. C.

"I remember the days when Professor Schaffner showed us that scum from the lake was full of marvels. I remember the classes in the old building which, they now tell me, is to be torn down. I remember the occasional gentle exasperation of Prof. Schaffner over the laggard understanding of the boys and girls that botany was a science, and not "just leaves." I remember our wide eyes when we were told that in some European universities Ohio State University in America was known merely as the location of Professor Schaffner. I remember when you and he were married. And now the years have passed and you have three children for which I am glad. And you have lost him, and we have lost him, and I'm sorry."

CHARLES J. CHAMBERLAIN, University of Chicago.

"Schaffner came to the University of Chicago in the autumn of 1896, attracted by the prestige of John Merle Coulter, who had become our first Head Professor of Botany. He was doubtless attracted also by the brilliant young palaeontologist, Dr. George Bauer, who had excellent material from the Galapagos Islands. He studied throughout the year with Bauer. His principal work, however, was in botany. Schaffner knew that most of Coulter's work had been of the "Gray's Manual" type of botany, but he also knew that Coulter was dissatisfied with the Rochester Code and was making the Engler and Prantl system, with its series of evolutionary lines, the basis for a more natural taxonomy.

This system, with a series of life histories, was the basis for the earlier courses in morphology at the University of Chicago.

Schaffner took the advanced morphology in Gymnosperms and Angiosperms. He also engaged in research in morphology throughout the year and published two papers which became classics, the life history of Sagittaria and the Macrospore Nucleus of *Lilium philadelphicum*.

On account of the unfortunate wording of the title of the *Lilium* paper, it was many years before Schaffner received the credit he deserved. In this paper he proved that Strasburger and Guignard, leaders in cytology of that day, were wrong in their claim that in the reduction of chromosomes in Angiosperms, there is a double longitudinal splitting. Schaffner described a transverse splitting at the second division. Later it was shown that Schaffner's transverse splitting was a separation of whole chromosomes. This, however, was comparatively unimportant, because Schaffner had proved a qualitative division in the Weissman sense instead of a quantitative division as Strasburger and Guignard claimed. Schaffner's figures show the situation as it is now seen with the most approved technique.

Schaffner was a profound thinker and an enthusiastic investigator, full of initiative, and he brought to our new department as much as he gained from it.

Schaffner and I became warm friends and, although technically I was instructor and he student, our relations were throughout those of colleagues.

He probably thought I was somewhat in advance, at least in taxonomy, but this was really not the case. For two seasons an undergraduate who had tramped the Chicago area for years with the Professor of Botany of the old University had taken me with him to collect material for classes made up largely of high school teachers. He knew all the ferns, flowers, and shrubs, so that I already knew many of the plants of the dunes region which were new to Schaffner.

Schaffner came to the University of Chicago expecting to take the Ph. D. degree, but in the spring quarter he was called to Ohio State University.

Schaffner and I have kept in contact with each other, and I regard him as one of the foremost botanists our country has ever produced."

H. A. GLEASON, New York Botanical Gardens.

"I was 22 years old when I applied and received a fellowship at Ohio State University. Having lived in the college town where I received my undergraduate training, it was also my first year away from home. For this reason, as well as my age, I was in a rather receptive mood and I had not been at Ohio State very long before I began to profit by my contact with Schaffner. Officially, I had nothing to do with him. I was assistant to Kellerman; as such I had charge of the herbarium, helped Kellerman in one or two of his classes, and during the first term registered for work under him in the graduate school. From this work I learned nothing, nor did I absorb much more from the minor courses which I took outside the Department of Botany. As a result, I did little or no class work during the second term, and had not registered at all during the third term.

I must have become acquainted with Schaffner very shortly after my arrival in Columbus. He was then a tall and very bashful man in his thirties. He occupied the very poorly equipped laboratories on the second floor of the old botany building, consisting, as I recall them, of one room of about 15x30 and another about 15x15. I do not remember whether he had an office of his own, or not. In the larger room were a few tables and a long table built against the wall, extending one full side and across one end. Here his handful of students sat on stools to carry on their laboratory work which was mostly morphological in nature. From time to time, I used to listen to his lectures. These were delivered to the floor, not to the students, in a sort of rambling, drawling monotone. I do not think his students, sophomores and juniors mostly, got much instruction or inspiration from them.

Schaffner and several of the graduate students were inveterate workers. I arrived at the building every morning at 7:45, and, except for two intervals for meals, kept steadily at it until eleven in the evening. Schaffner was always there late in the afternoon, and very frequently back again at night. Then with none of the formality of the classroom, we had dozens of interesting discussions, all of Schaffner's bashfulness and diffidence was forgotten and the arguments swept back and forth from one to the other until it was time to go home and to bed. Our discussions were mostly on evolution and phylogeny and Schaffner was loaded to the brim with ideas on both. Today, I do not remember a single point which was brought out in any of these numerous discussions, but I can say that the importance of phylogeny was so firmly impressed upon my mind that it was never forgotten, and that as a result I have consistently ever since attempted to introduce phylogenetic ideas into all of my taxonomic research.

The first Mrs. Schaffner was then alive. I must have seen her several times; I remember nothing about her activities or interests. I picture her now as a comparatively small but plump woman with a round rather attractive face and black hair, smoothly brushed down. It seems to me also that Schaffner addressed her as Mabel.

The graduate students at that time, if this will be of any interest to you, included Lumina Riddle, Clara Mark, Mabel MacKinley, Caroline Cormack, Jim Macowen, H. H. York, and myself. There may have been a few others; if so, I have forgotten them. We used to have many good times together, to which Kellerman and Schaffner were sometimes invited, and which they always seemed to enjoy very greatly. I remember one of these on Hallowe'en in 1904, when the girls cooked an oyster supper in the laboratory with the two professors as our guests.

H. H. York, as you must know, is now Professor of Botany at the University of Pennsylvania and it is possible that he can give you some further light on Schaffner. I have no idea what has happened to the others."

B. W. WELLS, North Carolina.

"As my mind goes back to the Ohio State days and I view the scene with the long perspective of twenty-eight years, one of the few monadnock's rising sharply from the campus plain is the towering intellect of Professor Schaffner. It was this quality of intellectual vigor and the tremendous range of his knowledge which resulted from it, that made Professor Schaffner one of the greatest botanists of his time. To have studied under him was one of the special privileges of my life.

As an undergraduate I worked in the 'Old Botany Building' above the Spring. There in addition to the prosecution of his cytological and systematic researches which he energetically carried on with his teaching, he had another self-imposed duty and that was the protection of the museum from the rain. As regularly as the showers came Professor Schaffner would quickly distribute the nondescript collection of pans, knowing from long experience just where the worst leaks were located. Instead of allowing the disturbing influence of a disintegrating building to affect him, he compensated for the building's deficiencies and carried on—the work, his botanical study was above everything to him and he conveyed this enthusiasm to his students who sometimes needed it when they too suffered from the rain or cold.

Professor Schaffner was at his best in conversation with his students and associates. He was almost a spendthrift with his time when it came to helping his students to a deeper insight into the special fields in which he was interested. I profoundly realize now that many horizons are broader today simply because Professor Schaffner took me on some of his long excursions in the realm of scientific and philosophical biology

It is with greatest satisfaction that I record my profound appreciation of the personality and activities of one of the most virile and original thinkers, painstaking investigators and inspiring teachers who has appeared in the field of American Botanical Science."

ROBERT F. GRIGGS, George Washington University.

"John H. Schaffner was one of the two or three men who most influenced my development. Upon analysis of my debt to him as compared with that to others who took the trouble to give of themselves to a young boy, it becomes clear that he contributed more to my store of factual materials and more especially to the biological principles developed from those facts than did any other.

He had, it seems to me, two outstanding endowments. The first I have already suggested. His remarkable mind. The second would come under the head of heart.

He had none of those easy tricks of a good mixer which make it possible for a man really of mediocre caliber, of the cheer-leader type, to carry with him a noisy crowd of rotarians, and so Schaffner was short of what commonly goes by the name of 'personality.' But he had something far finer though it did not bring him so much in the way of promoting his own advancement.

I have seen him sit by the hour discussing philosophy and religion with some student who after being brought up in a narrowly orthodox home found himself all at sea in the free atmosphere of the university. Not a few of our alumni, who have lived the most valuable lives, owe their orientation to his clear vision of fundamental moral and religious issues and his willingness to help them over the difficult transition from juvenile to adult philosophy.

I have often wished I knew more of his early years. Growing up largely alone on the Kansas prairie he never had the training in dealing with people which would have made him a leader of men. But somewhere in that lonely farmhouse there must, I think, have been keen intellects which contributed a rich heritage, and trained the mind of the boy in no ordinary fashion. One thing that makes me think that at least one of his parents must have had an exceptional mind is the fact that his sister was for a long time consultant to the Wisconsin legislature, drafting laws and advising as to social and legal progress the world over—certainly a position which required a high order of intellectual discrimination.

Schaffner's mind had a most remarkable clarity, carrying him straight to correct conclusions regardless of authoritative opinion to the contrary. Perhaps the best illustration of this quality was his early discovery, before the turn of the century, that there was a true reducing division in the meiosis of plants. In those days the dogma of the great German cytologist, Strasburger, ruled American laboratories to such an extent that they could see only what Strasburger had found. Strasburger held that the reduction division consisted of two equational splits of the chromosomes, so that any differential sorting out of chromatin material between the daughter cells was impossible. Schaffner, studying his slides saw a true reduction division, insisted on it, and would not recant. But his professors would not let him publish his results and he was not sufficiently pugnacious to fight the matter through to a successful issue. A year or two later Mendel's law was rediscovered, it became clear that a true reduction was required to explain the facts of alternative inheritance. Then everybody could see what he had found and reducing divisions were described from every laboratory.

If Schaffner could have dominated authority and compelled the publication of his findings, he would have become the leader in the new cytology which developed our present far flung chromosome theory of heredity."

Firman E. Bear, Rutgers, New Jersey.

"Professor Schaffner was an embodiment of the best in a man of science. His vast store of knowledge in his field made him so humble that folks passed him by without realizing who he was, or what he stood for. I am glad to have been numbered among his students and friends."

L. E. Melchers.

"The passing of Prof. John Henry Schaffner brought definite memories of him and Ohio State back to me.

The opportunity to have had worked with a man of his character and ability is an enviable experience. Why, as a student, was I drawn to Prof. Schaffner and what did I admire about him?

I admired his modest, unassuming, unselfish manner; characteristic of his everyday life. He never was too busy with his own research and interests to assist students and seemed especially patient in helping someone who could not comprehend some point in botany. I still can see him explaining a point to some student, spending hours, first from one approach then from another angle.

I remember Professor Schaffner best in the environment of the 'old botany building,' where I studied botany at Ohio State. He created an atmosphere which I enjoyed. The old, inadequate, under-equipped botany building, long ago a thing of the past,[10] was my choice of places on the campus—it wasn't the building that counted—there was my teacher who was a master of numerous fields of botany. I loved his enthusiasm, his sense of humor, his contagious chuckle, for he always could see a funny side of things. The loyalty to his host of friends and his helpfulness to a fellow in trouble was well known. Little did I dream that I would locate in the state most often mentioned by him—Kansas. He inspired me to seek the truth, to be alert and accurate in my observations, and certain of my conclusions.

I shall not review his scientific contributions, but I wish to mention one of the many, which is outstanding; his work on the 'nature and control of sex.' John H. Schaffner in the botanical world is a famous name. Well may Ohio State be proud of having had on its roll such a faculty member. It is a cherished memory to have studied with this teacher and to have had him as my friend."

A. B. Stout, New York Botanical Gardens.

"There are nearly fifty reprints in my files that bear the name 'John H. Schaffner' and several of these have the handwritten notation 'With the author's regards.' Most of these publications deal with the phenomena of sex in plants. They emphasize the physiological and developmental aspects of sex expression. They survey in a very comprehensive way sex behavior in the entire plant kingdom. There are extensive observations of the actual conditions and there are numerous important results of experimental studies, especially on the influence of environmental factors on the expression of sex. To me these papers have, through these various years, brought much of inspiration and I for one am glad to record my indebtedness to the work and the writings of John H. Schaffner."

---

[10] This building was turned over to the State Department of Health when the present Botany and Zoology Building was completed in 1914.

CHAS. C. DEAM, Bluffton, Indiana.

"My personal acquaintance with Professor Schaffner began at an annual meeting of the A. A. A. S. about 30 years ago. He religiously attended the meetings of the American Association of Science and I met him almost annually at them. I associated with him at these meetings more than with anyone else. I found him always the same congenial fellow. His habits were exemplary. His life from boyhood to the end was one of simplicity. His deportment, language, and his writings all follow this law of simplicity. His writings evince a vast store of fundamental knowledge which he used to work out his theory of plant evolution. This achievement will always remain as a monument to his industry, research, and logical study.

As a teacher he was unexcelled. I know two of his pupils who now hold the chair of botany, one in a college and one in a university, who told me of his ability and how they revered him. His hobby, a study of the Equisetaceae, made him the foremost authority on the genus Equisetum of North America. When discussing with him the Indiana Equiseta, I recall how well he knew our species in every detail. The achievements of Prof. Schaffner are surely enough to satisfy the aspirations of the most ambitious."

THE OHIO JOURNAL OF SCIENCE

VOL. XLI JULY 1941 No. 4

EDITOR'S NOTE

The Publications Committee of the Fiftieth Anniversary Celebration of the Ohio Academy of Science presents herewith further material relevant to the Celebration. This material includes a brief history of the Academy, prepared by the Historian, Mr. William Alexander. The history is followed by a series of plates portraying the charter members of the Academy, and the officers of the Academy at the time of the Celebration. The collection and arrangement of these pictures is due to the tireless work of the Academy librarian, Mrs. Ethel Miller.

Because of the change in method of election of section officers and the coincident change in the Secretaryship, the Proceedings of the Fifty-first Meeting have been delayed and will be printed in a later issue.

THE OHIO ACADEMY OF SCIENCE

(Mostly Historical)

WILLIAM H. ALEXANDER,
Academy Historian,
Normandie Hotel, Columbus, Ohio

PART ONE. DESCRIPTIVE

The story of Science in its simple, literal meaning, "ordered knowledge of natural phenomena," is a very old, a very long, and at the same time an intensely interesting one. Ancient man of necessity began very early to observe the natural phenomena about him and much of the knowledge thus gained has come down to us, often in the form of "myths," but after all a myth is simply man's earliest effort to *explain* some natural phenomenon. And even now, with all our boasted knowledge, we find ourselves "entangled in the web of existence, and we cannot get out of it, even for a brief moment, to see what the web is like." Furthermore, as we follow the course of Science through the years, we come upon many discarded theories, many abandoned organizations, for no sooner is a scientific theory advanced than an organization for its defense and promulgation appears. And while theories and organizations may come and go, SCIENCE MARCHES ON! However interesting and profitable it unquestionably would be to follow the march of Science through the ages, our immediate concern is with a very, very tiny portion of it that began right here in Ohio some fifty years ago, namely, the *Ohio Academy of Science.*

Going back, let us say, to the year 1890, what do we find in the field of science?—A large number of *local scientific groups*, clubs, societies, etc., at least as many as there were colleges and universities, and probably more, all more or less unrelated, disconnected and independent of each other. Beneficial? Useful? Certainly they were serving a definitely useful purpose but in the fertile brain of one William R. Lazenby, at that time a professor at Ohio State University, the belief that the best interests of science and scientists would be served by a state-wide organization took deep and permanent root. This idea flowered forth on November 3, 1891, in an earnest, almost prophetic appeal to his fellow scientists and to the members of the Biological Club of the Ohio State University of which Club he was then president, to the effect that immediate steps should be taken looking toward the organization of an *Ohio Academy of Science.* The appeal bore fruit at once and a committee of three (D. S. Kellicott, W. A. Kellerman, W. R. Lazenby) was appointed by the Biological Club, with instruction to proceed at once to carry out the suggestions of its president, and to call an organization meeting at the earliest possible date. So after some two months had been spent canvassing the field, the committee felt the time propitious and therefore issued the call. Accordingly, one bleak December day, December 31, 1891, at 2:00 P. M., to be exact, a group of earnest, forward-looking, determined men met in the old Central High School building, corner Broad and Sixth streets, Columbus, and bravely, wisely tackled the job assigned to them, namely, the organization of an Ohio Academy of Science. How well they builded, let the record of the past fifty years bear witness!

Unfortunately space will not permit an extended discussion of the personnel of this notable group! Truly some great spirits were there, as shown not only by what they did at the time, but by their achievements since that historic date. The pathway of some led them to great eminence in the greatest institutions of learning in the land, such as Princeton, Columbia, and Vassar. What fine lives they have led! How fortunate we are to have among us today at least nine of these honored names! (See Exhibit 1.) Look on these faces!

At this point it seems appropriate to make one or two rather extended quotations from one of the chief actors in the chain of events we are trying to portray, since these will throw further light on the character and wisdom of the fathers of the Ohio Academy of Science. First, a few words from the appeal of William R. Lazenby to the Biological Club on November 3, 1891, advocating the organization of a state academy:

> "There is need of one institution in Ohio to the organization of which our club should direct its combined energy and influence. This is a state academy of science. If local clubs and societies of science are beneficial, the reasons that make them so apply with greater force to a state organization. Who can estimate the inspiration, the stimulus to research and investigation that such an institution would provoke? * * * Once organized, I am sure the Ohio Academy would be a signal

and all-inspiring success, and could scarcely fail to secure an honored position among scientific organizations of our country."

Twenty-five years later he wrote these words:

> "Our annual meetings have confirmed and strengthened a spirit of good will between the educational institutions of the state. They have cultivated the amenities and developed a feeling of brotherhood among our members. Our academy has stood for good scholarship and good fellowship, and good citizenship. The essentials of a great landscape are unity and variety. These are likewise the great attributes of an association for the promotion of science. Unity in the spirit and ideals of the work to be accomplished, and variety, infinite variety, in the means by which these ideals may be developed. We come together on the basis of commanding interests and diverse experiences. This devotion to the varied phases of science detracts nothing from the pursuit of the older humanities, but adds materially to the effectiveness of any study that puts the student in closer touch with his environment, in closer touch with nature's laws."

What a masterful conception and statement of the functions of an organization! But back to our meeting on December 31, 1891.

Dr. A. M. Bleile was chosen temporary chairman and Prof. William R. Lazenby temporary secretary of the organization meeting. While a duly appointed committee was preparing a constitution for the new society, some ten papers selected from the 26 or more submitted were read and discussed. We note with pleasure that one of the ten papers read and discussed was by one of the nine now living charter members of the Academy, our own beloved and highly honored Joseph N. Bradford, on the subject, "Photography in Scientific Work." The list of papers prepared for this meeting shows a remarkable range of subjects.

The constitution formed and adopted at this first meeting gave to the new organization the name of the *Ohio State Academy of Science* and it was so designated until 1914 when the word "State" was dropped and the name became the *Ohio Academy of Science*, as at present. No material changes were made in the constitution until 1939 when the Council form of government was adopted.

The objects or purposes of the Academy as set forth in the constitution were two: (1) The promotion of scientific research; (2) The diffusion of knowledge concerning the various branches of science. The Academy was incorporated under the laws of Ohio on March 12, 1892.

The first constitution made no provision for the organization of special groups or sections, covering special fields of scientific endeavor, but the objects of the Academy were very satisfactorily accomplished through general meetings, general programs and the discussion of topics of general interest down to and including the year 1907. In 1908 two sections, "Biology" and "Geology," were organized and the other sections came along about as shown in Exhibit 13. Thus at the end of the first half century we find an academy of approximately 500 members with ten live, wide-awake sections, the last but not least, certainly for long, being the Section of Junior Academy of Science. More about this later. It may be interesting at this time to note that during the fifty years covered by this discussion 3,829 papers and lectures were presented to the general and sectional meetings of the Academy. One can hardly imagine the variety to be found in this vast array of scientific lore.

Coming now more directly to the two distinct objects of the academy, the promotion of research and the diffusion of scientific knowledge, much might be said regarding the accomplishments of the academy during the past fifty years. Fortunately for the academy, among the stalwarts who cherished and nourished it in its infancy were those who gave generously both of their time and means. Outstanding among these was Mr. Emerson McMillin who, as early as 1898, inaugurated a fund in aid of research by a gift of $250.00, which sum he continued to give annually up to the time of his death in 1922. To the McMillin Fund were added from time to time certain allotments from life memberships, and, since 1937, annual contributions from the American Association for the Advancement of Science, so that, to date, approximately $6,000 has been given in aid of more than sixty projects. The McMillin grant has stimulated a good deal of activity which has continued through the years and furnished a fund, the income from which has made it possible to continue grants in aid of research after Mr. McMillin's death. We very much regret that space will not permit the publication of a complete list of the various projects aided from the research fund of the academy, especially as such a list is the only way of showing the wide range in the scientific field covered by the work of the academy. To quote from the last report of the chairman of the Research Fund for the past several years, Dr. Herbert Osborn:

> "It seems very evident from this record that the McMillin Fund has been exceptionally serviceable in the encouragement of research work. It is certain for some of these studies the small allowance for certain kinds of expense was the particular thing which made possible the carrying on of the studies, resulting in the preparation of matter which has been of distinct value to the science of the state, and often of interest outside of state borders. The nature of the grants has been indicated in some of the records given above, but it may be noted further that they have included expenses involved in field trips, especially for problems in geology, botany and zoology, for apparatus in chemistry and physics, and in some cases for publication where there was need in this direction."

The Trustees of the Research Fund have been rather liberal in their construction of the term "research" and have not hesitated to extend aid in the publication of the results of research projects where this was necessary to make the results available. In Exhibit 9 is given a list of 21 special papers the publication of which was sponsored by the academy and all these from 3 to 19 inclusive received aid from the research fund. In a few cases the trustees even granted aid in the purchase of necessary apparatus.

As to the diffusion of scientific knowledge, the academy has always made much of the "printed word." It has always had an "official organ"; first, the *Journal of the Cincinnati Society of Natural History*, and the technical series of *Bulletins of the Ohio Agricultural Experiment Station;* in 1903 the *Ohio Naturalist* became its official organ and remained so until 1915 when the *Ohio Journal of Science* was made the official organ, and still is. Of course the lecture platform is used by many members of the academy in the diffusion of scientific information and even the radio has come into general use.

This leads up to another very important method of dissemination of scientific facts generously used by the academy, and that is through a system of exchanges. See Exhibit 11 and note that the academy is now receiving some 800 publications annually from 153 domestic and 282 foreign exchanges. These are available not only to members of the academy but to all students of science. This fact taken in connection with the statement above that approximately 4,000 scientific lectures and papers have been delivered and read before the academy during the last 50 years gives some idea as to what the academy is doing to spread the facts about science.

Reference has already been made to the organization of a Junior Academy of Science, designated as a section of the academy. The importance of this step warrants some further details, finally leading up to its consummation. The Ohio Academy of Science was by no means the first to organize a junior academy of science; in fact it has been a little slow. The agitation for a junior academy had its genesis at the Springfield meeting of the Ohio Academy, when on April 27, 1929, at the suggestion of the secretary, the following motion was approved by the academy:

> "That a committee of three be appointed by the president to consider the advisability and the ways and means of establishing facilities for encouraging junior scientific effort in Ohio and report with recommendation at the next annual meeting of the Academy."

Very appropriately, Dean Charles G. Shatzer of Wittenberg College was made chairman of that committee, and after three or four years of faithful effort the committee came to the conclusion that the time was not quite but almost ripe for the inauguration of a Junior Academy, and so reported to the Academy, with the recommendation that the matter be allowed to remain in abeyance until conditions seemed a little more propitious. This recommendation was approved and except for a little prodding now and then by the secretary no further serious effort was undertaken until 1939 when President Claude E. O'Neal revived the matter in real earnest. While little was actually accomplished during his administration other than "stirring the waters," fortunately he was succeeded by one equally as zealous for the project, namely, President William Lloyd Evans. Then, too, there arrived on the scene about this time the very man to head the committee charged with the arduous work of organizing the forces involved in the person of Prof. Charles W. Jarvis, of Ohio Wesleyan University. A more fortunate selection could scarcely have been made, as the results abundantly demonstrate. Assured of an efficient leadership, the Council gladly authorized, sponsored and actively supported a *trial junior academy meeting*, same to be held as a part of the semi-centennial celebration. The trial meeting was held on May 11, 1940, and was addressed by Dr. Otis W. Caldwell, General Secretary of the American

Association for the Advancement of Science, thereby adding considerable stimulus to the meeting.

Some 65 students from high schools well distributed over the state participated in this trial meeting, presenting some 67 papers in the fields of mathematics, physics, chemistry and biology. These papers were read, judged and rewarded. In addition to the papers, several very interesting demonstrations and quite an impressive array of exhibits were sponsored by the students. In short, the trial meeting was such an eminent success, even surprising the most sanguine expectations, that the Academy readily approved a recommendation of the Council that the Junior Academy be made a permanent organization as an integral part of the Senior Academy, same to be temporarily designated as a section of the Academy, practically self-governing with its own constitution, by-laws and officers. Of course Professor Jarvis was elected chairman, and Mr. Orval Linebrink secretary for the ensuing year.

Any history or "story" of the Ohio Academy of Science would be quite incomplete without some account of the Semi-Centennial Celebration, one if not *the* most important single event of the entire fifty years. At one time it was hoped ample space would be provided in which to do full justice to this truly great scientific event; to those who labored from one to four years in its accomplishment, giving freely of their time, talent and even means. In the opinion of some it is just here that the academy made its greatest mistake, or to use an old homely saying, more expressive, perhaps, than elegant, "The Academy swallowed the whole hog and then choked on the tail!" It looks, therefore, as if many of those who performed a noble, meritorious part in making the semi-centennial the success it undoubtedly was will have to be content with the *reward of the Unknown Soldier!* But even so, history insists that we be *fair*, be *just*, be *honest!* Silence in itself is not necessarily ethical, in fact may be just the opposite, even downright dishonest, especially if some one is thereby deprived of his justly merited share of praise. Therefore, at the risk of being severely criticized, for we are not unmindful of the risks involved when one begins to "call names," we propose to call a few names; truly wish we could call the entire roll.

The story of the semi-centennial of the Ohio Academy of Science had its inception in the meeting of the Executive Committee held in the New Secor Hotel in the City of Toledo on April 9, 1936, when, at the suggestion of the secretary, it was voted to make the following recommendation to the Academy, viz.:

> "That action be inaugurated at this meeting looking toward a suitable observance of the Fiftieth anniversary of the organization of the Academy four years hence and to this end the Committee suggests the appointment of a special committee on ways and means, to report at the next annual meeting of the Academy."

On the second day of the meeting (April 11), Dr. F. C. Waite, of Western Reserve University, referring to the foregoing recommendation, offered the following motion, which the Academy unanimously passed, viz.:

> "That the incoming President appoint a preliminary committee of five on plans for the celebration of the 50th anniversary and that this committee be charged to make a definite report of plans at the meeting next year."

In compliance with this action of the Academy, President Charles A. Doan appointed the following persons on this special committee, viz.:

Frederick C. Waite, Herbert Osborn, Walter H. Bucher, William Lloyd Evans and the Secretary, chairman.

This committee became immediately active and by personal interviews and by correspondence invited suggestions from every source that seemed available to it at the time, and after a year of earnest, conscientious effort it came to the next annual meeting (May 14, 1937) with the following preliminary report, viz.:

Report of the Preliminary Committee on 50th Anniversary of the Ohio Academy of Science

COLUMBUS, OHIO, May 14, 1937.

To the Ohio Academy of Science:

Your Committee appointed by President Doan, pursuant to a motion passed at the Toledo meeting of April, 1936, submits the following report:

We heartily commend the celebration of the semi-centennial of the *Ohio Academy of Science* and believe that this should be done in a distinctive and comprehensive manner that will not only commemorate what has been accomplished in the past fifty years, but will also stimulate yet greater endeavor in the future. We hope that the program will be sufficiently worthy that the proceedings when published will be a real contribution to the literature of science and of scientific organizations.

To this end we make the following recommendations:

1. That the 50th Annual Meeting be held at the Ohio State University in Columbus, the birthplace of the Academy, in 1940, the month and days to be designated later.

2. That the meetings of 1938 and 1939 be held elsewhere than in Columbus.

3. That the 50th meeting be devoted entirely to the semi-centennial celebration, consisting of two major parts, one *historical* and the other *scientific.*

4. That the meeting be organized and carried through by a Director and ten committees.

5. That the Director have general supervision of the entire celebration and be ex-officio a member of each committee.

6. That the Nominating Committee for the 1938 meeting present one or more suggestions for the position of Director and that their suggestion or suggestions for this position be announced at the first business session of the meeting of 1938 and voted on at the final session of that meeting.

7. That the committees be grouped into two groups on the basis of the sequence of their activities.

8. That each committee consist of not more than three members, and that not more than one honorary member may be, but not of necessity must be, added to each committee.

9. That the committees be as follows:

GROUP A

(1) On Publicity, both preliminary and current.
(2) On Program.
(3) On Speakers, including guests.
(4) On Invitations.
(5) On Historical Statistics and Lists.

GROUP B.

(6) On Exhibits.
(7) On Memorials.
(8) On Dinner.
(9) On Finances.
(10) On Publications.

10. That the Executive Committee choose and appoint at least the chairman of each of the five committees in Group A, not later than December 1, 1937, with the expectation that a preliminary report from these five chairmen will be presented at the 1938 meeting.

11. That the completion of all committees be accomplished not later than December 1, 1938, and that all committees report either separately or through a general report by the Director at the 1939 meeting.

Respectfully submitted with the understanding that when amended and adopted the carrying out of these recommendations be the duty of the officers and executive committee of the Academy.

(Signed) W. H. ALEXANDER, *Chairman*,
F. C. WAITE,
HERBERT OSBORN,
WALTER H. BUCHER,
WM. LLOYD EVANS,

The preliminary report with its various recommendations apparently met with the hearty approval of the Academy and the new President, Dr. Claude E. O'Neal, of Ohio Wesleyan University, devoted himself with unusual zeal, tact and foresight to the numerous problems involved in the project. His first great concern was, of course, to find a suitable Director. After a most careful, thorough canvass of the field, all signs seemed to point to the late beloved Dean of the Graduate School at Ohio State University, Prof. George F. Arps, and with remarkable unanimity the Academy turned to him for leadership. Tactfully approached regarding the matter by President O'Neal and his supporting officers the beloved Dean graciously accepted the office of Director of the Semi-Centennial, and everybody was more than happy, for Dean Arps was known to be a past master in such matters. For a time all went well. Rapid progress was made by the Director and the President in the appointment of committees, the development of the details of a most ambitious celebration, the raising of the necessary funds, and so forth, when lo, tragedy entered! The "grim reaper" came and removed our trusted leader! The blow was staggering. Confusion ensued for a time. To whom could we now turn? When, lo, Providence entered!

About this time Dr. William Lloyd Evans, of Ohio State University became President of the Academy. He was one of those who had worked out the preliminary plans for the celebration, and was therefore most helpful and sympathetic from the very beginning. So all eyes turned to the new President and his generous heart was already deeply enmeshed with the best interests of the Academy and of course he could not refuse the importunities of his fellows, "his partners in distress." Accordingly, he assumed the double role of President of the Academy and the Director of the Semi-Centennial. And with what rare skill and wise counsel he carried on to a grand finale, every one knows. "Well done, good and faithful servant!"

Another major problem pressing for solution was that of building a program in keeping with the high aims of the promoters of the celebration, really the *sine qua non* of the whole affair. Who could organize such a program and secure the necessary talent? Here again rare wisdom was shown in the selection of the chairman of the Program Committee, in the person of Dr. Clarence H. Kennedy, of Ohio State University. Such a task is difficult enough under the most favorable circumstances but when beset with severe financial limitations it becomes even more difficult. Dr. Kennedy's task was made somewhat more difficult by an early decision to the effect that only talent from outside the state would be used on the program. Fortunately, however, this restriction was later removed and several of our distinguished Ohio scientists were on the program. The masterly manner in which Dr. Kennedy and his committee handled the building of a notable program is abundantly attested by reference to the printed, official anniversary program and to the array of fine papers published in the May issue of the Ohio Journal of Science. Congratulations, Dr. Kennedy!

Another faithful worker whose arduous labors must not be overlooked was the chairman of the Finance Committee, Dr. H. H. M. Bowman, of the University of Toledo. The solicitation of funds with which to finance a celebration of this kind does not, as a rule, lend itself to the spectacular; only hard work and monotonous drudgery are involved, with disappointments a-plenty. Dr. Bowman and his committee are worthy of the highest commendation for a job well done.

One of the greatest surprises, certainly one of the most impressive features, of the semi-centennial was the number and variety of exhibits, both centralized and fixed, provided for the inspection of visitors. All credit and praise for this part of the semi-centennial belong to Chairman Glenn W. Blaydes and his loyal, efficient committee.

Verily "the first shall be last and the last first!" Who of all those having any part, however minor it may have seemed, in the success of the semi-centennial has not, at one time or another, found himself or herself knocking at the door of our patient, hard-working, indefatigable, resourceful librarian, Mrs. Ethel M. Miller! No matter what one wanted to know about this or that meeting, this or that person, this or that thing, it was always, "See Mrs. Miller!" She never failed us. Hats off to Mrs. Miller!

Part Two. Statistical

Exhibit 1. Charter Members

C. E. Albright	Columbus
A. M. Bleile	Columbus
*L. M. Bloomfield	†Columbus ‡R. F. D. No. 2, Lancaster, Ohio
E. E. Bogue	Orwell
R. D. Bohannan	Columbus
*J. N. Bradford	†Columbus ‡55 E. Oakland Ave., Columbus
H. E. Chapin	Athens
E. N. Claassen	Cleveland
E. W. Claypole	Akron
A. D. Cole	Granville
F. J. Combs	Columbus
*Edwin G. Conklin	†Delaware ‡Princeton University, Princeton, N. J.
George W. Dean	Kent
H. J. Detmers	Columbus
Freda Detmers	Columbus
F. J. Falkenbach	Wooster
A. Feiel	Columbus
Kent O. Foltz	Akron
Sara F. Goodrich	Geneva
W. J. Green	Wooster
*G. P. Grimsley	†Columbus ‡Baltimore, Md.
L. W. Gunckel	Dayton
Seth Hayes	Cincinnati
J. S. Hine	Columbus
L. A. Hine	Sandusky
T. F. Hunt	Columbus
Davis L. James	Cincinnati
Reynold Janney	Chillicothe
H. L. Jones	Granville
W. A. Kellerman	Columbus
Mrs. W. A. Kellerman	Columbus
D. S. Kellicott	Columbus
William Krebs	Cleveland
William R. Lazenby	Columbus
J. U. Lloyd	Cincinnati
N. W. Lord	Columbus
L. H. McFadden	Westerville
*C. B. Morrey	†Columbus ‡South Miami, Fla.
*E. L. Moseley	†Sandusky ‡Bowling Green, Ohio
E. T. Nelson	Delaware
Edward Orton	Columbus
A. N. Ozias	Columbus
A. D. Selby	Columbus
C. E. Slocum	Defiance
Ellen E. Smith	Painesville
H. P. Smith	Portsmouth
Henry Snyder	Oxford
William Soule	Alliance
*H. A. Surface	†Columbus Selinsgrove, Pa.
B. F. Thomas	Columbus
*A. L. Treadwell	†Oxford ‡Vassar College, Poughkeepsie, N. Y.
*George R. Twiss	†Columbus ‡Ft. Myers, Fla.
Lewis Ullrich	Tiffin
H. A. Weber	Columbus
F. M. Webster	Wooster
William C. Werner	Columbus
Jane F. Winn	Chillicothe
A. A. Wright	Oberlin
J. B. Wright	Wilmington

---

*Living. †Address in 1891. ‡Present address.

Note: Mr. Surface died July 8, 1941.—W. H. A.

EXHIBIT 2. APPROXIMATE MEMBERSHIP AT END OF EACH YEAR

(Figures in parentheses indicate number new members elected during the year.)

1891	59*		1907	203	(20)	1923	324	(25)
1892	117		1908	209	(25)	1924	372	(59)
1893	136		1909	197	(16)	1925	396	(46)
1894	130		1910	183	(8)	1926	442	(69)
1895	158		1911	197	(13)	1927	484	(69)
1896	158		1912	218	(32)	1928	†	(53)
1897	162		1913	232	(48)	1929	589	(66)
1898	164		1914	234	(24)	1930	607	(94)
1899	180		1915	254	(41)	1931	612	(70)
1900	173		1916	268	(17)	1932	467	(58)
1901	165		1917	258	(11)	1933		(28)
1902	158		1918	245	(11)	1934	537	(28)
1903	166		1919	284	(40)	1935	472	(22)
1904	161	(15)	1920	299	(30)	1936	385	(41)
1905	182	(28)	1921	325	(47)	1937	399	(39)
1906	195	(26)	1922	326	(46)	1938	500	(61)
1939	560	(68)	1940	575	(127)			

---

*Charter members. See Exhibit 1.
†List not published but given as "a few over 500."

EXHIBIT 3. LIFE MEMBERS

EMERSON E. MCMILLIN	1892–1922; died December 31, 1922.
FRANK R. VAN HORN	1921–1933; died August 1, 1933.
CLINTON R. STAUFFER	1930–
S. PRENTISS BALDWIN	1930–1938; died December 31, 1938.
S. CHARLES KENDEIGH	1930–

EXHIBIT 4. PATRONS

C. E. SLOCUM	1908–1915; died June 7, 1915.
EMERSON E. MCMILLIN	1920–1922; died December 31, 1922.
GEORGE T. SPAHR	1929–1939; died September 12, 1939.

EXHIBIT 5. HONORARY MEMBERS

THOMAS CORWIN MENDENHALL	1912–1924; died March 22, 1924.
F. A. MCCLURE	1937–

NOTE: Approximately 400 members have been made fellows of the Academy.

Exhibit 6. Time of Annual Meetings

Nos. 1 to 10 (1891–1900), held late in December (Christmas Holidays).
Nos. 11 to 25 (1901–1915), held late in November (Thanksgiving Time).
Nos. 26 to 50 (1916–1940), held in the Spring (Easter Vacation Time).

(The meeting time was changed to the Easter Vacation season at the 25th Annual Meeting, 1915.)

Exhibit 7. Places at Which Annual Meetings Have Been Held

(With number of times at each)

Akron	1	Columbus	29	Oxford	2
Athens	1	Delaware	2	Springfield	1
Cincinnati	4	Granville	2	Toledo	1
Cleveland	3	Oberlin	2	Wooster	2

Exhibit 8. Past Officers

(1) PRESIDENTS

*.	A. M. Bleile	1891	25.	George D. Hubbard	1916
1.	E. W. Claypole	1892	26.	Frederick O. Grover	1917
2.	Edward Orton	1893	27.	F. L. Landacre	1918
3.	F. M. Webster	1894	28.	Maynard M. Metcalf	1919
4.	D. S. Kellicott	1895	29.	F. C. Blake	1920
5.	A. A. Wright	1896	30.	William H. Alexander	1921
6.	W. A. Kellerman	1897	31.	Raymond C. Osburn	1922
7.	W. G. Tight	1898	32.	Albert P. Weiss	1923
8.	G. F. Wright	1899	33.	Kirtley F. Mather	1924
9.	Josua Lindahl	1900	34.	E. N. Transeau	1925
10.	A. D. Selby	1901	35.	Paul M. Rea	1926
11.	William R. Lazenby	1902	36.	William McPherson	1927
12.	C. J. Herrick	1903	37.	Harris M. Benedict	1928
13.	E. L. Moseley	1904	38.	James S. Hine	1929
14.	Herbert Osborn	1905	39.	Frederick C. Waite	1930
15.	Edward L. Rice	1906	40.	August F. Foerste	1931
16.	Charles Dury	1907	41.	Alpheus W. Smith	1932
17.	Frank Carney	1908	42.	Robert A. Budington	1933
18.	John H. Schaffner	1909	43.	E. Lucy Braun	1934
19.	W. F. Mercer	1910	44.	James P. Porter	1935
20.	Lewis G. Westgate	1911	45.	Walter H. Bucher	1936
21.	Bruce Fink	1912	46.	Charles A. Doan	1937
22.	L. B. Walton	1913	47.	Charles G. Shatzer	1938
23.	Thomas C. Mendenhall	1914	48.	Claude E. O'Neal	1939
24.	J. Warren Smith	1915	49.	William Lloyd Evans	1940

---

*Chairman of the organization meeting only.

(2) SECRETARIES

1.	William R. Lazenby	1892	4.	F. L. Landacre	1904
2.	W. G. Tight	1893–1894	5.	L. B. Walton	1905–1912
3.	E. L. Moseley	1895–1903	6.	Edward L. Rice	1913–1922
7.	William H. Alexander	1923–1940			

(3) TREASURERS

1.	A. D. Selby	1892–1895	5.	Wencel J. Kostir	1919
2.	D. S. Kellicott	1896–1898	6.	A. E. Waller	1920–1936
3.	Herbert Osborn	1899–1904	7.	Eugene Van Cleef	1937–1939
4.	James S. Hine	1905–1918	8.	E. S. Thomas	1940–

Exhibit 9. Special Papers

1. Sandusky Flora. pp. 167. E. L. Moseley.
2. The Odonata of Ohio. pp. 116. David S. Kellicott.
3. The Preglacial Drainage of Ohio. pp. 75. W. G. Tight, J. A. Bownocker, J. H. Todd and Gerard Fowke.
4. *The Fishes of Ohio. pp. 105. Raymond C. Osburn.
5. Tabanidae of Ohio. pp. 63. James S. Hine.
6. *The Birds of Ohio. pp. 241. Lynds Jones.
7. Ecological Study of Big Spring Prairie. pp. 96. Thomas A. Bonser.
8. The Coccidae of Ohio. I. pp. 66. James G. Sanders.
9. Batrachians and Reptiles of Ohio. pp. 54. Max Morse.
10. Ecological Study of Brush Lake. pp. 20. J. H. Schaffner, Otto E. Jennings, Fred J. Tyler.
11. The Willows of Ohio. pp. 60. Robert F. Griggs.
12. Land and Fresh-water Mollusca of Ohio. pp. 35. V. Sterki.
13. The Protozoa of Sandusky Bay and Vicinity. pp. 52. F. L. Landacre.
14. Discomycetes in the Vicinity of Oxford. pp. 54. Freda M. Bachman.
15. *Trees of Ohio and Surrounding Territory. pp. 122. John H. Schaffner.
16. The Pteridophytes of Ohio. pp. 41. John H. Schaffner.
17. Fauna of the Maxville Limestone. pp. 65. W. C. Morse.
18. The Agaricaceae of Ohio. pp. 116. W. G. Stover.
19. An Ecological Study of Buckeye Lake. pp. 138. Frederica Detmers.
20. Flora of the Oak Openings West of Toledo. pp. 56. E. L. Moseley.
21. The Cedar Cliffs Prairie Opening of the Cincinnati Region. pp. 36. N. Mildred Irwin.

---

*Out of print.

Exhibit 10. Sales of Publications

Receipts

1903–1904—Treasurer's report shows sales amounting to	$ 5.09
1904–1914—W. C. Mills, librarian in charge, sales of	311.69
1915–1923—C. W. Reeder in charge, sales amounted to	252.42
1924–1925—Miss Alice McKee in charge, sales reached	65.89
1926–1940—Mrs. Ethel M. Miller in charge, sales reached	701.54
Adding to these receipts bank dividends on funds on deposit, 1926–1937, the sum of	37.00
We have total receipts of	$1,373.63

Expenses

1899—Cost of Special Papers Nos. 1 and 2 (Exhibit 9)	$160.00
1904–1914—Postage paid by W. C. Mills, librarian	316.78
1929—Cost of Special Paper No. 21	210.00
Total expenditures	$686.78
1903–1940—Leaving a cash balance of	$686.85

N. B.: The postage on Academy publications since 1915 has been paid by the Ohio State University Library thus saving to the Academy the entire sum of the balance noted above.

EXHIBIT 11. EXCHANGES

1905. W. C. Mills, librarian, in charge of Academy exchanges; at this time exchanges were being received from 26 scientific societies and colleges.

1909. Academy publications were being sent to 16 scientific societies and to two foreign museums, Buenos Aires and the British.

1915. The Ohio Academy of Science library was deposited in the Ohio State University Library and C. W. Reeder placed in charge of the exchanges. Mr. Reeder immediately inaugurated an intensive effort to secure additional exchanges, the net result of his effort being some 200 new titles.

1921. Another effort to secure more exchanges was made but with less satisfactory results.

1924–25. Miss Alice McKee was in charge of the exchanges.

1926. Following the departure of Mr. Reeder from the library, Mrs. Ethel M. Miller was placed in charge of the Academy exchanges and through her wise, persistent efforts 34 new exchanges were added the first year and the list has continued to grow ever since.

1941. As a result of the faithful efforts of the afore-mentioned persons the Ohio Academy of Science now has on its exchange list 153 domestic and 282 foreign exchanges, or a total of 435. The number of publications received is approximately 800, as many institutions send several titles.

EXHIBIT 12. CHAIRMEN SEMI-CENTENNIAL COMMITTEES

GROUP A

1. *On Publicity:* EDWARD S. THOMAS, Ohio State Museum.
2. *On Program:* DR. CLARENCE H. KENNEDY, Ohio State University.
3. *On Speakers:* FRANK J. WRIGHT, Denison University.
4. *On Invitations:* DR. RAYMOND C. OSBURN, Ohio State University.
5. *On Historical Statistics and Lists:* DR. SAMUEL RENSHAW, Ohio State University.

GROUP B

1. *On Exhibits:* DR. GLENN W. BLAYDES, Ohio State University.
2. *On Memorials:*
3. *On Banquet:* DR. F. C. DOCKERAY, Ohio State University.
4. *On Finances:* DR. H. H. M. BOWMAN, University of Toledo.
5. *On Publications:* DR. HENRY C. SHETRONE, Ohio State Museum.
6. *On Housing:* DR. FRED A. HITCHCOCK, Ohio State University.

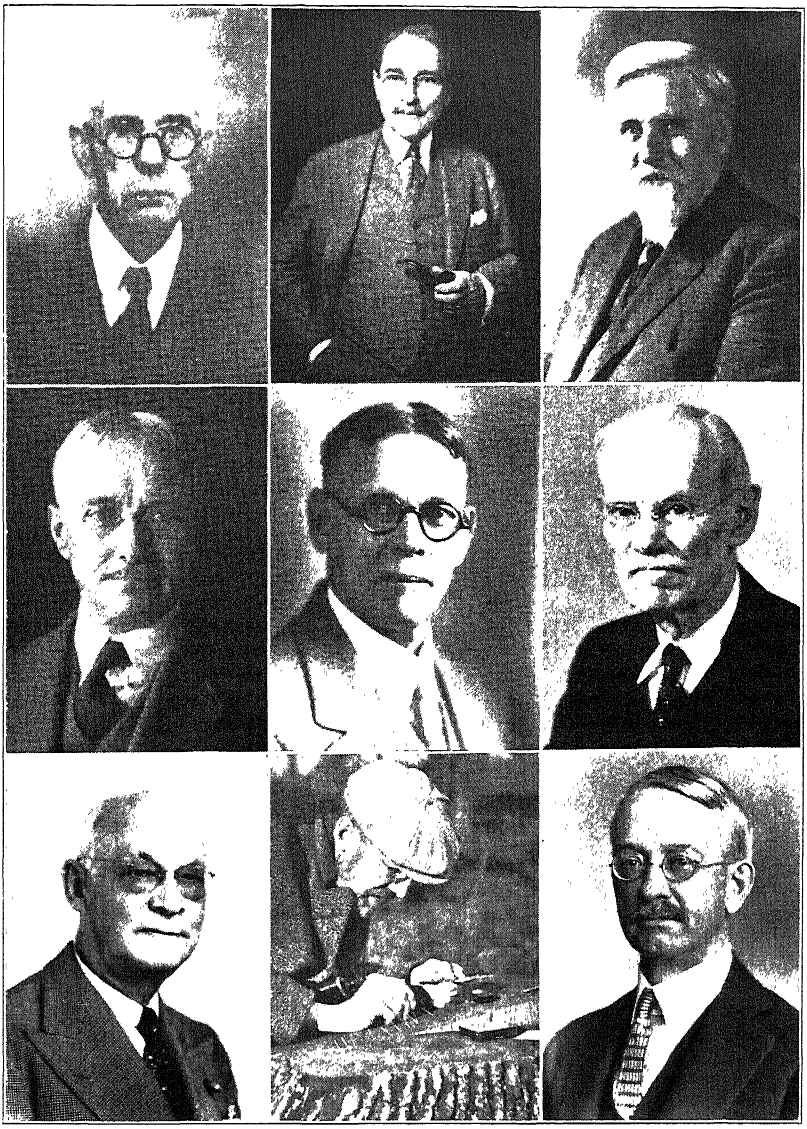
EXHIBIT 13. FORMATION OF SECTIONS

1891–1907. No separate sections.
1908. Biology, Geology.
1909. Biology was divided into Botany and Zoology.
1912. Physics.
1917. Anatomy, Physiology, later known as the Medical Sciences.
1919. Psychology.
1924. Name of the Physics Section changed to the Physical Sciences.
1932. Geography.
1933. Chemistry.
Section of Physical Sciences changed to "Physics and Astronomy."
1938. Mathematics.
1940. Junior Academy of Science.

Exhibit 14. Grants from the Research Fund

1899.	W. G. Tight, J. A. Bownocker, J. H. Todd, R. C. Osburn	$160.00
1900.	Gerard Fowke, R. C. Osburn, T. A. Bonser, J. S. Hine, E. B. Williamson	164.45
1902.	J. S. Hine, Lynds Jones, F. L. Landacre, Max Morse, J. H. Schaffner	375.50
1903.	T. A. Bonser	50.00
1904.	F. L. Landacre, Max Morse, J. G. Sanders, J. H. Schaffner	100.00
1905.	R. F. Griggs, Herbert Osborn	67.92
1906.	W. B. Herms, J. E. Hyde, F. Carney, Chas. Brookover, Victor Sterki	173.65
1907.	W. C. Morse	50.00
1908.	A. Dachnowski, H. S. Hammond, S. Morgulis, L. B. Walton, Freda Bachman (project published)	99.09
1909.	J. H. Schaffner, L. B. Walton, Freda Detmers, A. Dachnowski, G. E. Coghill, R. J. Sim	179.73
1910.	J. H. Schaffner (for publication), A. Dachnowski, Freda Detmers, J. C. Hambleton	174.70
1911.	W. C. Morse, W. M. Barrows, A. Dachnowski	118.50
1912.	W. G. Stover, Freda Detmers, L. B. Walton, J. S. Hine, A. Dachnowski, W. J. Kostir	130.65
1913.	Clara Mark, A. Dachnowski, Chas. Brookover, Freda Detmers, S. R. Williams	196.80
1914.	J. S. Hine, F. B. H. Brown, O. W. Pflueger, R. F. Griggs, S. R. Williams, W. H. Shideler, L. B. Walton	295.40
1915.	F. C. Blake, Charles Sheard, L. B. Walton, W. H. Bucher, J. S. Hine, S. R. Williams	355.28
1916.	S. R. Williams and W. H. Shideler; L. S. Hopkins, B. W. Wells, F. L. Landacre	200.00
1917.	Forest B. H. Brown, B. W. Wells, W. L. DuBois, S. R. Williams, W. M. Barrows	169.04
1918.	G. D. Hubbard, E. L. Rice, L. B. Walton, E. N. Transeau, H. W. Lutz	215.12
1919.	J. S. Hine, W. H. Bucher	150.00
1920.	F. C. Blake, Paul B. Sears, W. H. Bucher, L. B. Walton, Elsie Jordan	323.21
1921.	Elsie Jordan, L. B. Walton	42.81
1922.	Paul B. Sears, J. S. Hine	56.20
1923.	L. B. Walton, F. H. Herrick, L. H. Tiffany, J. E. Kindred, E. L. Stover, R. A. Dobbins	300.76
1926.	W. M. Barrows	70.00
1928.	Bernard S. Meyer	50.00
1931.	Bernard S. Meyer, Paul B. Sears	73.55
1934.	W. L. Evans	100.00
1935.	R. B. Frost	100.00
1936.	J. P. Porter	75.00
1937.	D. C. Rife, Wayne M. Felts, R. A. Dobbins	275.00
1938.	G. D. Hubbard, Frank H. Verhoek	150.00
1939.	E. Lucy Braun, B. G. Anderson, C. A. Lawson	300.00
1940.	J. W. Frink, A. N. Solberg	150.00

PLATE I



LIVING CHARTER MEMBERS OF THE OHIO ACADEMY OF SCIENCE
1940

LLOYD MORRIS BLOOMFIELD

AARON LOUIS TREADWELL
Vice-President 1896

GEORGE RANSOM TWISS

GEORGE PERRY GRIMSLEY
Greystone Studios, Inc.

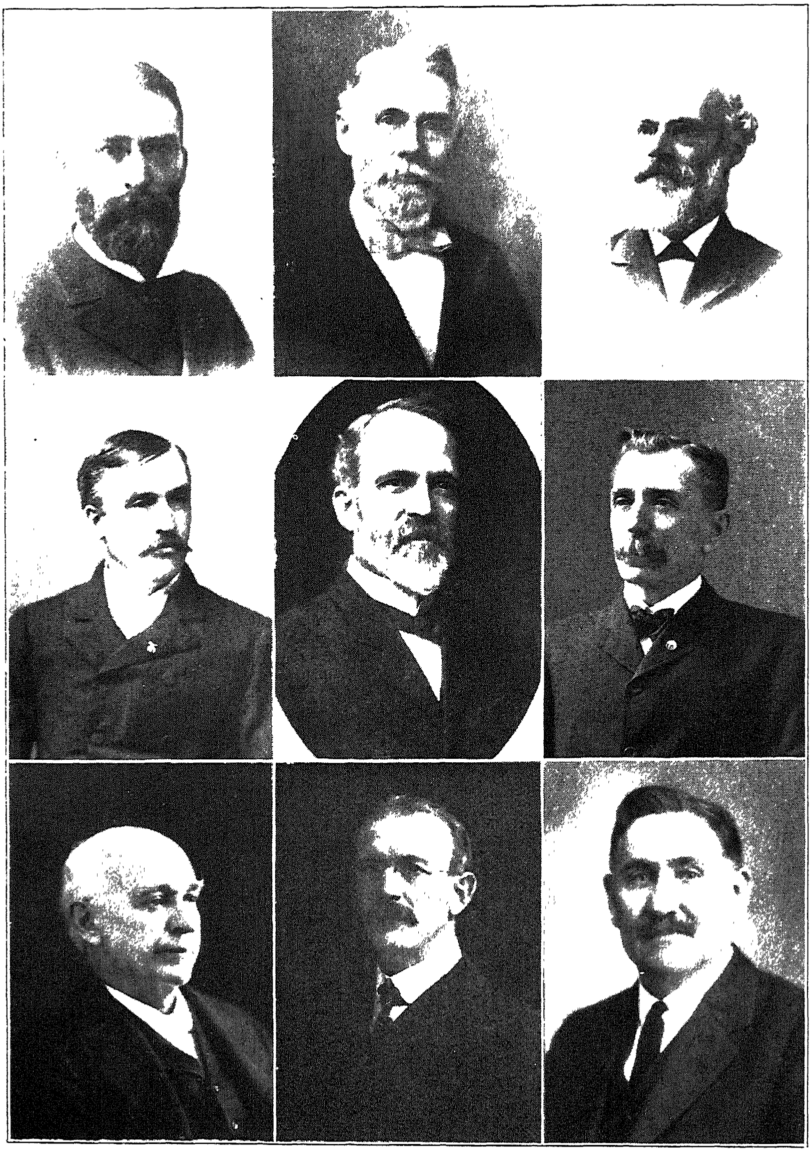
CHARLES BRADFIELD MORREY

EDWIN LINCOLN MOSELEY
Secretary 1895–1903
President 1904

HARVEY ADAM SURFACE
Died July 8, 1941

JOSEPH NELSON BRADFORD

EDWIN GRANT CONKLIN



CHARTER MEMBERS WHO BECAME PRESIDENTS OF THE OHIO ACADEMY OF SCIENCE

DAVID SIMONS KELLICOTT, 1895
Vice-President 1893
Treasurer 1896–1898

FRANCIS MARION WEBSTER, 1894

EDWARD ORTON, 1893

ALBERT A. WRIGHT, 1896
Vice-President 1892

WILLIAM ASHBROOK KELLERMAN, 1897

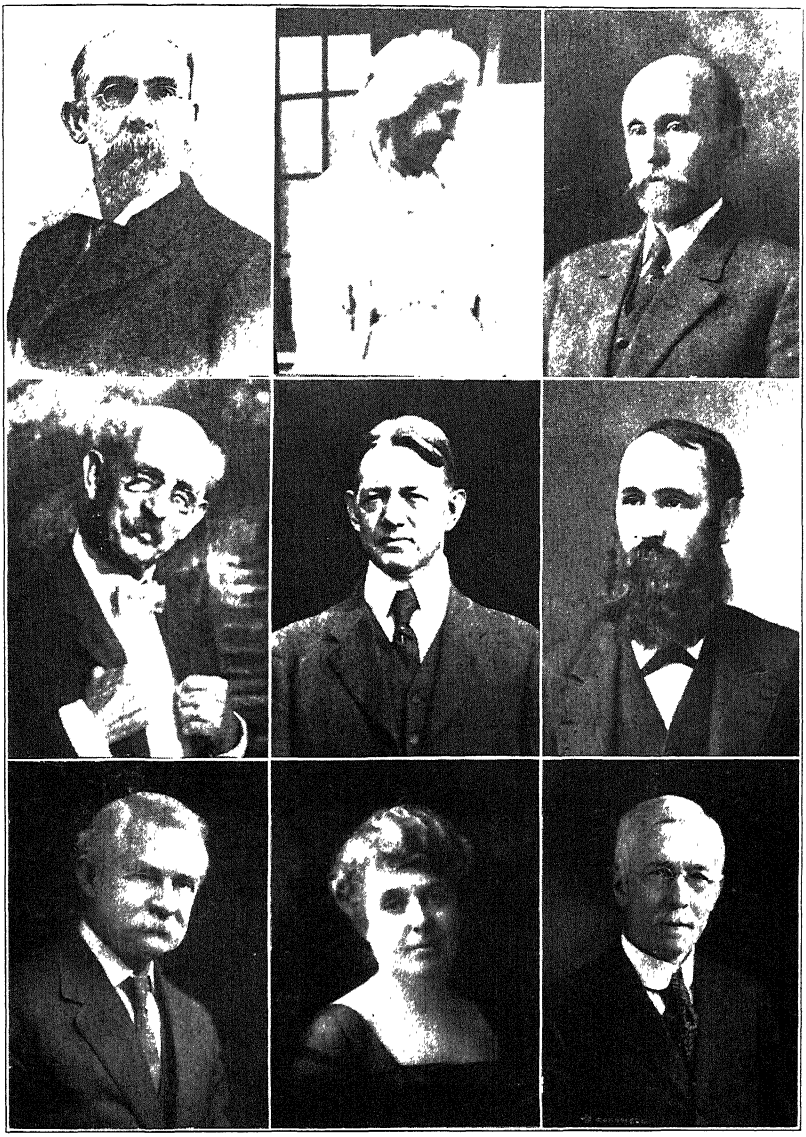
AUGUSTINE DAWSON SELBY, 1901
Vice-President 1899
Treasurer 1892–1895

EDWARD W. CLAYPOLE, 1892

WILLIAM RANE LAZENBY, 1902
Secretary 1892

JAMES STEWART HINE, 1929
Treasurer 1905–1919

PLATE III



CHARTER MEMBERS WHO BECAME VICE-PRESIDENTS OF THE OHIO ACADEMY OF SCIENCE

CHARLES ELIHU SLOCUM, 1897

CHARLES EDWIN ALBRIGHT, 1899

DAVIS LAWLER JAMES, 1893

MRS. WILLIAM A. KELLERMAN, 1894, 1901

ALFRED DODGE COLE, 1914

MISS JANE F. WINN, 1895

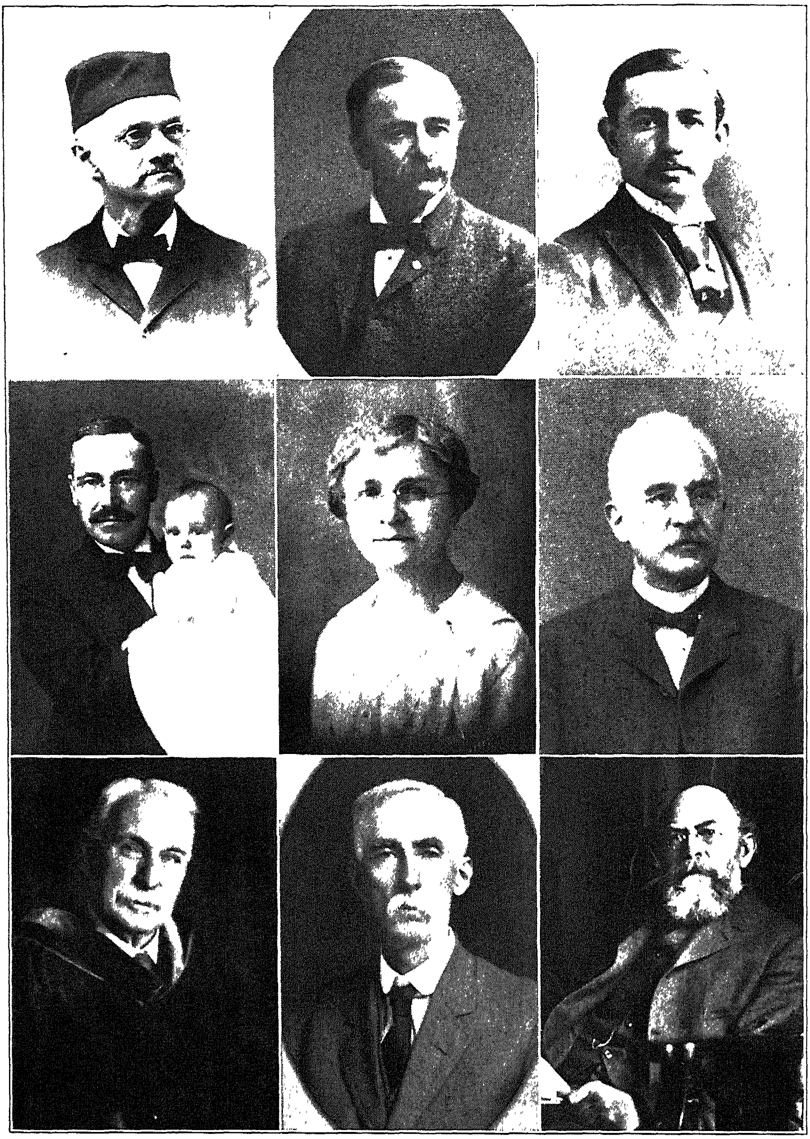
HENRY EDGERTON CHAPIN, 1895

J. B. WRIGHT, 1897

LOUIS H. MCFADDEN, 1904

Cornwell, Dayton, O.

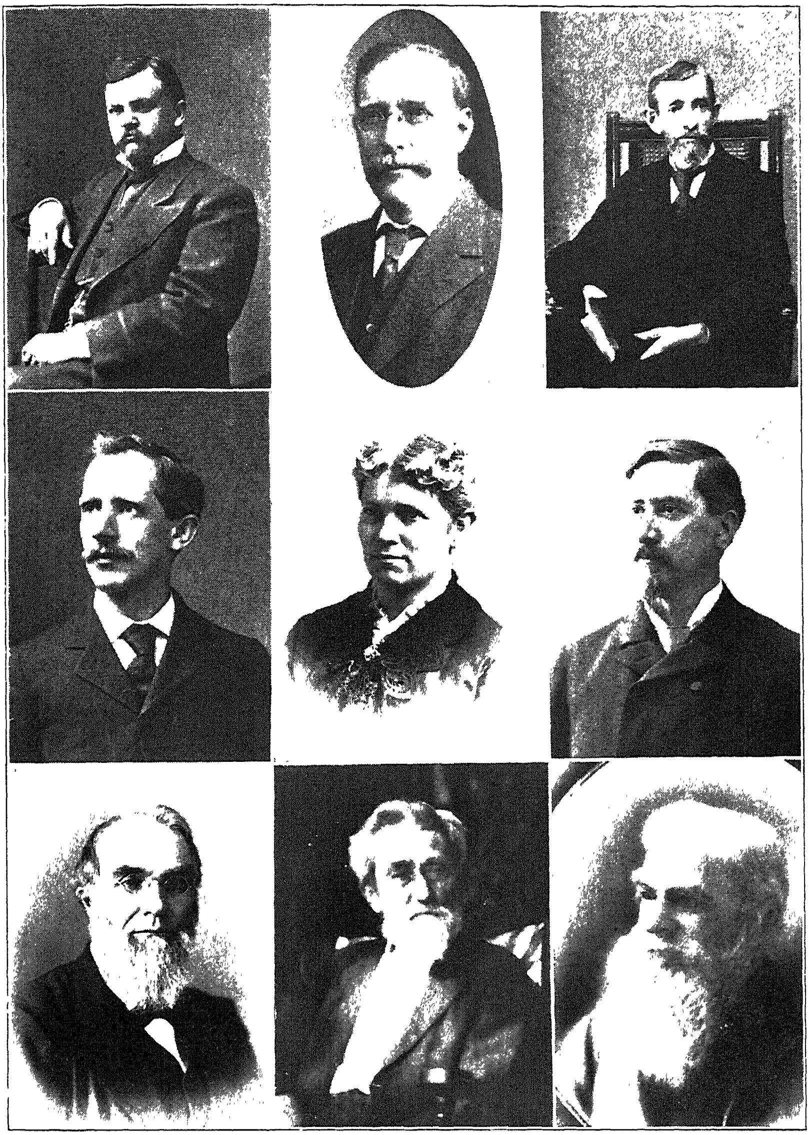
PLATE IV



CHARTER MEMBERS OF THE OHIO ACADEMY OF SCIENCE

WILLIAM KREBS	LEWIS ULLRICH	HERBERT LYON JONES
FRANK JOSEPH FALKENBACH	MISS FREDA DETMERS Vice-President 1918	ALBERT MARTIN BLEILE Chairman, Organization Meeting, December 31, 1891
ROSSER DANIEL BOHANNAN	WILLIAM JAMES GREEN	NATHANIEL WRIGHT LORD

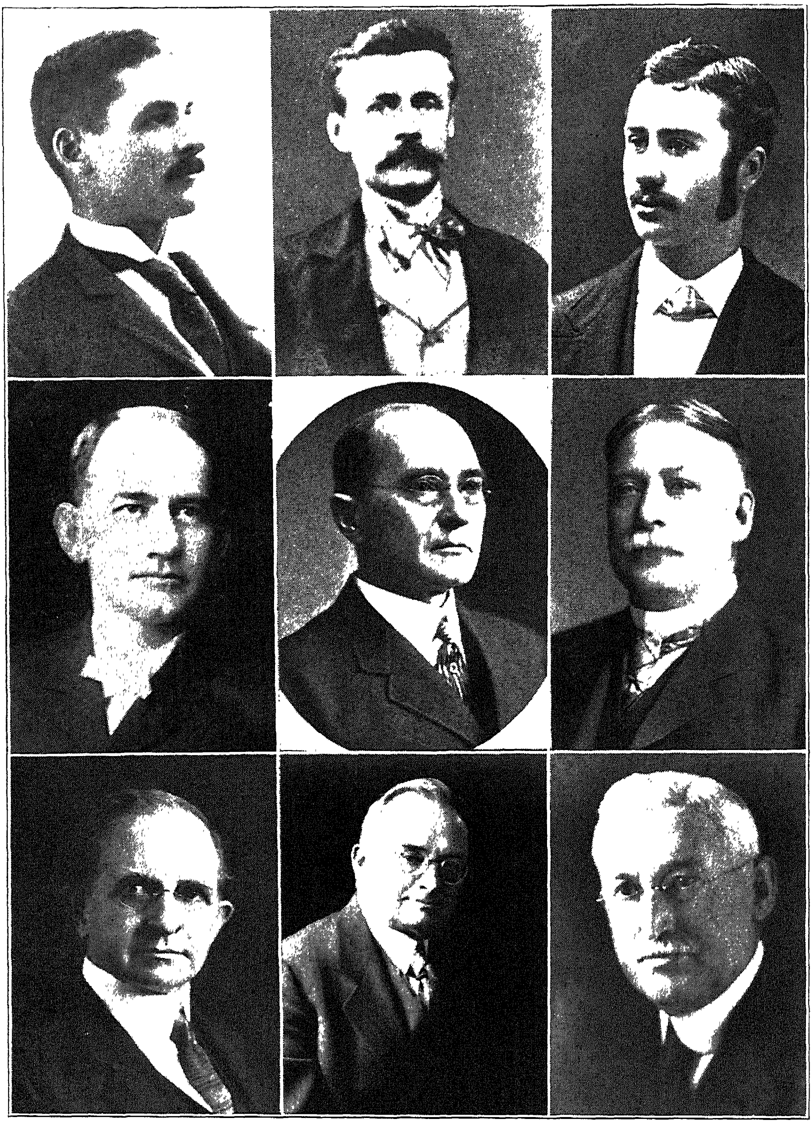
PLATE V



CHARTER MEMBERS OF THE OHIO ACADEMY OF SCIENCE

E. T. NELSON	KENT OSCANYAN FOLTZ	WILLIAM SOULE
HORACE P. SMITH	MISS SARA F. GOODRICH	BENJAMIN FRANKLIN THOMAS
GEORGE W. DEAN	EDO N. CLAASSEN	HENRY J. DETMERS

PLATE VI



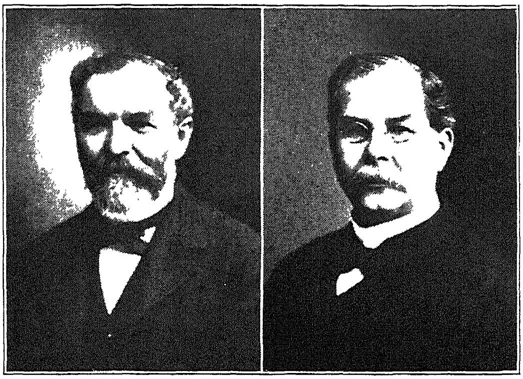
CHARTER MEMBERS OF THE OHIO ACADEMY OF SCIENCE

L. A. HINE HENRY SNYDER WILLIAM C. WERNER

ERNEST EVERETT BOGUE JOHN URI LLOYD ALBERT NEWTON OZIAS

REYNOLD JANNEY SETH HAYES THOMAS FORSYTH HUNT

PLATE VII

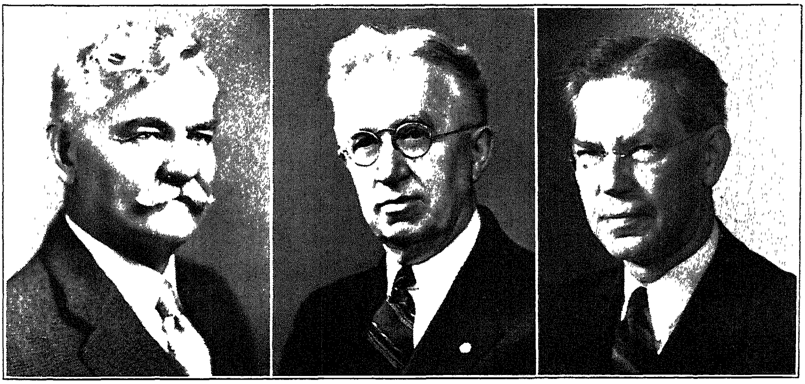


CHARTER MEMBERS OF THE OHIO ACADEMY OF SCIENCE

ADOLPH FEIEL HENRY ADAM WEBER

Pictures were not secured of Frank J. Combs, L. W. Gunckel, and
Miss Ellen E. Smith, Vice-President 1892

PLATE VIII



SEMI-CENTENNIAL OFFICERS OF THE OHIO ACADEMY OF SCIENCE
1940

WILLIAM HENRY ALEXANDER
Secretary

WILLIAM LLOYD EVANS
President

EUGENE VAN CLEEF
Treasurer

PRESIDENTIAL ADDRESS

(Fifty-first Annual Meeting)

THE SAGA OF THE PADDY'S RUN

STEPHEN R. WILLIAMS

INTRODUCTION

Thinking over the varied interests of our Academy audience, and the infinitesimal area in the field of zoology in which I might claim original knowledge, it seemed evident that were I to speak along that line tonight it would bore even the other zoologists.

There is however a matter of history which should interest you all as members of the Commonwealth of Ohio, which I have had especial opportunities to study from original sources. They say every man who is born has one speech in his make-up, and I hope for your sakes that this is mine.

You realize that we all have a good knowledge of the things of the present, and a fraction of what went on forty years ago which our parents knew. By the time we get to our grandparents, our fraction of their unwritten knowledge is a small one, and when it comes to great-grandparents, unless it has been written down where it may be read, one is exceptional if he knows the names of those eight persons, and can make a fifty per cent grade in answering the questions as to where they were born or married, or of what they died.

The modifications which produced the stage on which this history was enacted, the Paddy's Run Valley, have been taken from the Bulletin on the Geology of Cincinnati by Professor N. M. Fenneman.

THE PADDY'S RUN VALLEY

Preparation of the valley for the first settlers dates back to the time of the receding Wisconsin glaciation, perhaps 20,000 years ago. In the interglacial period between the Illinoian and Wisconsin ice sheets the Whitewater river, now a tributary of the Miami, emptied into the ancestral Ohio near the city of Harrison in Hamilton County. The old Ohio made an enormous north bend in the present city of Cincinnati, flowing northward through the present Mill Creek Valley to Symmes Corner in Butler County where the larger Miami entered it and the combined ancestral river bore off southwest toward New Haven and Harrison and beyond.

As the Wisconsin ice spread over the northwest two-thirds of Ohio the water melting from it formed a succession of long pools marking the bed of the present Ohio river. The lower end of one of these pools was at Anderson's ferry just west of Cincinnati. Following the course of two small streams, one flowing eastward toward Cincinnati and the other on the opposite side of the divide flowing toward the ancestral river south of Harrison, the accumulation of water cut through the hills and thereby eliminated the enormous Mill Creek, Symmes Corner, Harrison northward bend, giving us the present course of the Ohio river from Cincinnati to Lawrenceburg.

As the ice mass withdrew very slowly over the Symmes Corner-Harrison section of the ancestral river, by utilizing the valleys of certain small streams to the east and south of the ice front, the flood water cut a path from below Venice, by New Baltimore and Miamitown to the region of Cleves. This has been used by the Great Miami, whose waters follow first the old ancestral valley from Symmes Corner, then this narrower new valley to Cleves, and then are joined by the Whitewater from the north to reach the straightened Ohio below Elizabethtown.

This same lingering of the ice mass caused the stream now known as the Dry Fork of the Whitewater, which had entered the ancestral Ohio independently at Fernald, to skirt the ice and cut southward through a ridge, thereby reaching the ancestral Ohio bed much farther west and now emptying into the Whitewater River below Harrison. This new lower end of this stream runs over the thick deposit of gravel in the ancestral valley and as a consequence, except at flood times, the visible water is so much reduced that the early settlers called it the Dry Fork (of the Whitewater). The narrow, deep, steep incline of the cut through the ridge just mentioned was well adapted for an inexpensive mill dam and a short mill race, and here the first grist mill for the new settlers was located. The unused lower part of the old Dry Fork, together with the shorter branches from the east and north now forms a smaller separate stream entering the Miami below Fernald near where the newer narrow post glacial part of the Miami Valley begins. This is the Paddy's Run.

I cannot do better than to quote from Murat Halstead's picture of the Paddy's Run valley.

"The bosom of the valley was laced with a thread of silver; a stream—the home of sunfish—murmured and sparkled under lofty sycamores, statuesque, their arms white as marble, and lowly willows that drooped along the shining water like slender rods of gold. . . . The springs at the foot of the hills could be traced like veins in a leaf as little brooks to the larger stream in the center, that brightening with their increase, babbled over the polished gravel and glistening sand southward to the Great Miami and the greater and splendid Ohio."

No one knows whether the luckless Irishman, possibly one of Wayne's scouts—whether he actually was drowned or merely engulfed in the semi-liquid mud as he crossed the run following the west bank of the Miami north toward Hamilton. But the stream was named in his honor and later the postoffice of the same name in the village farther upstream was so distinctive that letters from Wales addressed to Paddy's Run, America, arrived safely.

THE INDIANS

In traditional times no Miami Indians lived the year round in this valley. They knew Kentucky as The Dark and Bloody Ground, and planned to spend their winters at least two days march north of the Ohio so as to avoid surprise attacks.

The narrow beaten paths through the woods along the tops of the hills possibly date back to the postglacial mammoths and mastodons whose bones two centuries ago gave the name to Big Bone Lick on the Kentucky side of the river below Lawrenceburg. These paths were certainly used by the buffalo (bison) as they made their way from one prairie opening or windfall to another. The explanation for the single file habitual to Indian warparties is that they followed these paths on their march.

Old Chief Kiatta and his daughter Okeana left their names—the one for a small tributary of Dry Fork, Kiatta Creek, and the other for the present village of Okeana in the center of Morgan Township, both near their summer residence on Camp Run.

Indians were not uncommon sights to the white settlers until the wholesale deportations beyond the Mississippi which occurred in the 1820's. Many of you have driven through

Miami, Oklahoma, a name which is a monument to the forced migration of one particular tribe.

THE WELSH IMMIGRATION

A majority of the early white settlers were Welsh. In 1795 a party of emigrants started from Llanbrynmair, Montgomeryshire, North Wales. Among them were George Roberts and wife, David and Mary Francis, Rev. Rees Lloyd, wife and children, and two young unmarried men, Edward Bebb and Ezekiel Hughes. Their plan was to be transferred by sail boat from the nearest point on Cardigan Bay to Bristol and there embark on the ship *Maria* for Philadelphia. For fear of the press-gang it was decided that the women only should sail with the luggage while the men, for safety's sake to avoid impressment as sailors, would walk the fifty or sixty miles to Bristol. Something delayed the expected freight boat a number of days. The alarmed women walked twenty miles toward Bristol and met the men coming back to find out what was the matter. The boat with the baggage must have come along and picked up the whole party because they reached the *Maria* at the last moment, after they had been given up, and the ship was about to start without them.

Landing at Philadelphia the party scattered. George Roberts and Rees Lloyd settled at Ebensburg, Cambria County, about the middle of Pennsylvania, the Francis's stopping near Philadelphia, while Bebb and Hughes, having no families, continued westward to Cincinnati, arriving in 1796. The Symmes Purchase land had been picked over and the land west of the Great Miami, not yet surveyed, was not on the market. There was nothing to do but wait. So they squatted on Blue Rock Creek in Colerain township, which, though in the Symmes Purchase, was so rough and broken as not to be in demand. Others of the Welsh families stopped in Blue Rock later for the same reason, and the first white child born in Colerain township was to one of these families.

When at last in 1801 the surveyed lands were available, Bebb bought half a section on the Dry Fork of the Whitewater in Butler County, while Ezekiel Hughes, being more of a plutocrat, bought two sections further south in Hamilton County. Since neither of these men was married, as soon as the farms were arranged for, they started on the long journey back to Wales for helpmeets.

Hughes, back home in Wales, married a Margaret Bebb, who may have been a sister of his friend Edward Bebb. To tell the Bebb story I shall have to leave Bebb and Hughes trudging along the roads eastward, and start back in Wales myself.

No letter, as far as we know, had come back from America during the years from 1795 to 1801 while the squatters were waiting for their land, and it may have been thought that the young fellows were dead. As a result Margaret Roberts, sister of George Roberts of the 1795 party, who had known Edward Bebbs, when they were children, had been urged by her family into marrying a Rev. Mr. Owens. Her older sister Grace, her husband and two children were planning to emigrate to America and Rev. Owens and his bride decided to accompany them. They started in 1801; the passage was long and tempestuous. Both husbands and Grace's two children died, reportedly from bad water, and were buried at sea. Another version of the story is that the captain and mate of the vessel, taking note of the two beautiful young women, took pains to poison the water for the unwanted relatives. At any rate for some reason, the two widowed sisters are said to have left the ship secretly at the Philadelphia dock, by sliding down a rope at the bow while the officers were superintending the regular debarkation. They made their way to their brother, George Roberts at Ebensburg, sending a messenger back to the ship to claim their abandoned belongings.

Believe it or not, two days after Margaret Roberts Owens reached Ebensburg, her childhood's acquaintance, Edward Bebb, walked in from his farm on Dry Fork. It did not take him long to decide not to go any farther towards Wales. They were married February 2, 1802, probably walked to Pittsburg, certainly floated from there to Cincinnati on a flatboat or broad-horn and reached the Dry Fork in time for Edward to do some spring planting. (The two-story log house in which the Bebbs set up housekeeping is still in use.) On December 8th, 1802, William Bebb, one of the subjects of this paper, was born.

FORMING THE COMMUNITY

For more than twenty years a stream of Welsh came to the Paddy's Run, and from it as the country opened, other Welsh settlements were made, notably in the regions of the headwaters of the Miami, Maumee, and Wabash from which the Indians had been sent west.

With neighbors helping, a comfortable log cabin could be built in two days and the amount of food obtainable was limited only by the rate of clearing the land.

Others appreciated the fertile soil of the Paddy's Run valley besides the numerous Welsh whom I have not attempted to name. Appleton, Blackburn, Carmack, Drybread, Halstead, Harding, Howard, Milholland, Parkinson, Phillis, and Shaw are names of families from the older states who settled in and about the valley.

James Shields, Glasgow graduate, was for many years the representative for Butler County in Columbus, and at least once was the district Representative in the capital at Washington.

CHURCH

After the settling, the first endeavor as a community was to start a church society. This was in 1803, the year Ohio became a state. The incoming Welsh were usually Nonconformists or dissenters from the English Established Church. Those from the Eastern States probably represented many different forms of worship. The story goes that the committee of five, who drafted a church constitution, were of five different church persuasions and that they chose the Congregational type because it was self-governing and because it was a church not represented by any committee-man.

Services were held at the cabins of different members, in a private school house, in a wagon-maker's shop, and in favorable seasons in a central grove of sugar maples. By 1825 a brick meeting house, now the community house, was erected in this grove.

SCHOOL

The first school was established in 1807, long before Ohio's public schools. The teacher boarded around in the homes from which the children came, and received in addition an honorarium of $0.75 per week.

In 1809 a subscription school charging $1.50 per child for a term of three months was started. They were taught reading, writing, and arithmetic, graduating at the Rule of Three.

In 1819 David Lloyd, graduate of the University of Pennsylvania, introduced grammar and geography, and separated his students into groups or classes. A letter from William Bebb to his sister, Mrs. Vaughn, speaks of the high quality of his teaching. He must have had a screw loose somewhere, however, as he is said to have spent most of his life trying to devise a perpetual motion machine.

In 1821 Rev. Thomas Thomas established a high school and boarding school in which he taught to advanced pupils grammar, geography, arithmetic, algebra, and geometry.

LIBRARY

In 1821 a bill was passed in the Ohio Legislature incorporating the Union Library Association of Morgan and Crosby Townships. Shares cost $3.00 and sixty-five were sold. The books were kept at the mill at the Dry Fork Cut previously mentioned because every family had to bring its wheat and corn there to be ground.

When the turnpike road was put through from Cincinnati to Brookville, Indiana, in 1838, this library was no longer located at a common meeting place, and was neglected.

About twenty years later a second subscription for a library followed renewed interest in the community, and at present the library is actively functioning.

WILLIAM BEBB (AND HIS SCHOOL)

William Bebb, oldest child of Edward Bebb and Margaret, his wife, was born in a frontier settlement in a frontier state, from foreign born parents who were seeking a livelihood and independence not possible in their native land. There were three Bebb children.

All the opportunities locally possible were given them. Very probably the first book teaching was done by the mother, but you may be sure that after the age of six or eight William Bebb had at least three or four months of schooling every year. We have his own appreciative evidence as the skill and information of David Lloyd and his very unfavorable comments on an earlier teacher. All the Bebb line have exceptional memories, ability to learn by observation, and then apply that knowledge with good judgment.

Naturally he and his brother worked on the home farm and neither ever lost his interest in things agricultural. During school sessions they would have regular chores, night and morning, for which they were held responsible.

We can infer that he was a fine student. He was examined for his certificate by James Shields, the Glasgow graduate, and began teaching the Paddy's Run district in 1826. His next school was at North Bend, the home of General W. H. Harrison. By 1828 he was married. Possibly influenced by the Thomas boarding school started in Paddy's Run some years before, the young couple started a boarding school on the Bebb farm for boys from 10 to 14 years old. It was a success from the start. There is nothing except the story of Robert Owen's New Harmony project going on about this same time in Indiana that is as spectacular as the few bits of information I have been able to gather about this Sycamore Grove school on Dry Fork.

If I knew all the high points of ultra-modern education I think I could show that Bebb had foreshadowed many if not most of them in his methods—(1) the development of interest and (2) of groups of related interests, (3) the project method with its plan, assembly, and completion, are perfectly evident. The freedom of the frontier encouraged direct attack on problems rather than following of traditional methods. Moreover, a perfectly strong healthy helpmeet with a genius for cooking and for handling boys was an asset which cannot be disregarded. I have been able to find nothing of such facts as the curriculum or tuition charged per term, but there is a letter describing the Bebb school in the *Enquirer* of September 14, 1879, by Judge A. W. C. Carter, who spent two years in the school, that is much more interesting.

The school house was just across the road west of the Dry Fork and faced east. The central part held the school rooms, the south wing was the boys' dormitory and Mr. Bebb and family lived in the north wing. There were 30–40 boarders from Cincinnati and the South, and a few local day pupils.

The year was divided into two five-month terms, with a month's vacation between each two terms. School hours each day were from 9 to 12 and from 2 to 5. The assembly room was 20 feet by 30 feet with rows of desks for the scholars on three sides and the teacher's desk on the fourth. In spite of the large wood stove in the center of the room and the fireplace in the dining room it was very cold in the winter time. According to Judge Carter there was no way of heating the dormitory and as the whole building was up on piers, chilblains and frosted feet were the usual thing. There were no washing facilities in the dormitory and any face or hand washing was done at the creek just over the road.

The boys were encouraged to build cabins of their own, and given the privilege of cutting logs from the woods along the stream. The more pretentious of these log cabins were two-room affairs with stone fireplaces and brick chimneys and during the winter were probably more comfortable than the frame dormitory. It was permitted to be out there in the evening but the boys all had to be back in the dormitory at Mr Bebb's inspection hour in the morning. It must have been an ideal life after the homesick period had passed. Skating, swimming, and fishing came in their seasons. The boys learned to cook the sunfish, catfish, chubs, suckers, goddle-eyes (rock bass), soft shelled turtles, snappers, crayfish, and rabbits in their fireplaces.

The orchards of the venerable "Uncle" or "Sir" (Edward) Bebb were free to the boys when the fruit was ripe, just so they did not club the fruit out of the trees. Every two boys, as partners, were assigned a plot of ground by William Bebb to raise what they liked best to eat. Probably there was some private agreement arrived at among the groups as to the diversification of food, and certainly there were few insect parasites to be fed then as compared to the present.

Mr. Bebb was justice of the peace and legal adviser for most of the inhabitants of Morgan township. The civil and criminal court cases were held in the assembly room with the boys (10–14 years old) all required to be present at their desks during the trials. What wonder many of his pupils grew up to become lawyers, judges, and political leaders?

About this time there was a period when military training for men came into fashion. According to Judge Carter, "Mr. Bebb was a militia commander and when in his regimentals, mounted on his black stallion on his way to the parade ground, he was a sight to us boys indeed."

Among the scholars who attended the Sycamore Grove school were Judge A. W. C. Carter, whose article is the source of my information.

William Dennison, Governor of Ohio, 1859–61.

Charles Larrabee, born in Rome, New York, 1820. His father was a major in the army and by appointment of President Jackson, 1828–36, was Surveyor of the Fort of Cincinnati. After the Bebb school closed in 1832 he attended an academy in Springfield and later Granville College (now Denison University). At twenty-four he went to Chicago to practice law. In 1847 he moved to Wisconsin where he lived for nearly twenty years. He was a member of the second Constitutional Convention of Wisconsin, was a circuit judge for ten years, Representative in Washington, 1858–60, in the Union Army as Captain, Major and Colonel, 1861–63, retired due to ill health. For the sake of his health he moved to the west. He became a member of the first Constitutional Convention of Washington Territory. Later he made his home near San Bernardino, California, practicing law and breeding new plants and fruits. He lost his life in a railroad accident, January 20, 1883.

Hon Dr. G. M. Shaw, of Indiana.

Hon. Daniel Shaw, Sheriff of Grant Parish, member of the Louisiana legislature.

Hon. Peter Melendy, of Iowa.

Hampton Davis, mayor of Vicksburg.

Augustus Jordan, prominent lawyer in New Orleans.

When in 1832 Mr. Bebb gave up Sycamore Grove and moved to Hamilton to take up the practice of law, the whole of Butler and Hamilton Counties and neighboring Indiana regretted the loss of the school.

HAMILTON, 1832–1850

Mr. Bebb was already well known in Hamilton since he had been one of the county teachers' examiners for years, and he developed a good law practice.

He did not lose his interest in teaching. In 1835 he drafted a bill to charter a female academy in Hamilton and became an adviser to the management.

He was interested in all public movements; was an ardent advocate of the educational values of County Fairs to the farmers and spoke for them at other county seats.

At the Buckeye Celebration, September 30, 1835, in honor of the completion of Fort Hamilton by General St. Clair forty-four years previously, Mr. Bebb was the orator of the day. He emphasized the merits of the Ordinance of 1787, and especially commended the exclusion of involuntary servitude from the Northwest Territory. He says, "we meddle not with slavery as it exists in the South. Only one catastrophe can arrest the onward career of the country, and that is a severance of the Union," so it is clear that both these questions were in the air at the time.

He took an active part in politics as a Whig and campaigned for William Henry Harrison in both 1836 and 1840. The election of Polk in 1844 settled both the admission of Texas in 1845 and the certainty of war with Mexico.

In 1846 he was elected governor of Ohio, the third governor born in Ohio and the first from the southwestern part of the state. The Mexican war was unpopular with the Northern Whigs because of the increase of slave territory. Elected governor by a party unfavorable to the war, and being himself against it, he nevertheless fell into line, believing that the loyal support of the Government was more important than consistency to a party.

The State House in Columbus had been authorized seven years earlier, but for some reason or other nothing had been done. He sent a message to the Legislature dealing chiefly with the construction of the State House, and though it was not completed for six more years, his prodding produced visible results. Ohio was very prosperous during his term of office, showing good money, advances in schools, activity in the construction of railroads and turnpikes, and good business conditions generally.

In his final message, printed in 1849, he said that the majority in the United States was against the extension of slavery into New Mexico and California, and that any compromise passed by Congress against the will of the majority would "cause the lightning to burst forth hereafter with more terrific and astounding effect."

His little daughter Sarah died of acute appendicitis (as we would call it now) in 1848, and was buried in Greenwood Cemetery which had been obtained for Hamilton in great part through his efforts.

Discouraged by the national prospects he decided to retire from the law. He purchased a large tract of land on Rock River in Illinois and in 1850 moved there, using the Miami and Erie canal to Toledo and a lake boat from there around the Soo to Chicago. With his household goods he took the coffin of his daughter from Greenwood, and she was buried in Illinois.

The slavery question was becoming more and more serious and many former Whigs were becoming black Abolitionists.

The Whig party and Henry Clay believed in compromise or appeasement as we speak of it today, and I think Governor Bebb went to his parents' old home in Wales in 1855 and arranged for a new Welsh colony to the United States with some such object as demonstrating the greater efficiency of free over slave labor in mind. In this colony were two of his own first cousins, Samuel and George Roberts. There is no reason why he should have chosen East Tennessee as compared with Illinois, Iowa, or even Wisconsin, for the location of the colony unless he hoped that the example to be set by the hundred industrious free Welsh he was helping over would tend gradually to educate the South away from slavery.

In May, 1857, his son Michael married and came to the Illinois home on the wedding trip. A number of the hoodlums of the neighborhood arranged an evening charivari or "belling," bringing guns and bells and flasks. Mr. Bebb ordered them off to no avail. They were too full of their artificial courage to be frightened off by firing over their heads. He fired again at a lower level and killed one of the roisterers.

He was tried for manslaughter in the Rockford County Court. It was a notable case. Two of his former coadjutors in Ohio courts, Ex-governor Tom Corwin of Lebanon, and Judge W. T. Johnston of Cincinnati, volunteered to assist his Rockford attorneys for old friendship's sake. The trial lasted four days and the jury after deliberating four hours brought in a verdict of Not Guilty. The notes of Governor Corwin's speech were filed with the official papers as wonderful oratory and convincing argument.

Since the Welsh colony in Tennessee needed superintending and legal guidance the family moved south, and Mr. Bebb began the practice of law in Knoxville. His son Edward drove 200 sheep from Rockford, Illinois, to Huntsville, Tennessee, between December 19 and January 10, having been snowed up once in Indiana.

In January, 1860, Mr. Bebb wrote his sister in Paddy's Run: "We have been received with marked attention and friendship by the people of Knoxville. Nine-tenths of them are old Whigs of the Henry Clay school. I apprehended that we might find trouble in the present excited state of public opinion but I have not seen or heard anything unkind toward the people of the North."

However, in a letter from Knoxville six months later, Mr. Bebb, after speaking of the railroad he had hoped to encourage the business men of Cincinnati to start (the present Cincinnati Southern) and telling of half a dozen law cases he had conducted in Knoxville and vicinity, hopes that he can devote the rest of his life to his profession *which he should never have quit* (italics his). He then says to his sister: "The more I see of slavery the less I like it. Not because the slaves are not well treated but because of its general influence upon the whites and upon the industrial and moral trend of society. We have an excellent house, much like our Hamilton house, and a good garden. We have one good colored girl whom we hire at $6.00 per month."

Mr. Bebb made a few speeches in Illinois that summer in favor of Lincoln and word was sent him that he had better not come back to Tennessee. His Welsh colony also was scattered all over the northern United States by the Civil War. After his family left their home it was broken into and looted by Southern sympathizers. His portrait as Governor of Ohio was slashed with a saber. Later some of his possessions were reclaimed and sent to Washington where he was employed as Pension examiner from 1861 to 1869. The damaged portrait is still in Washington, the property of one of his grandsons.

At home in Rockford he took pneumonia due to exposure undergone when returning from making a speech in favor of Grant as President. It was his first serious illness in his whole life and he never fully recovered. He died in Rockford October 23, 1873.

His son, Michael Schuck Bebb, was a well known amateur botanist and correspondent of Asa Gray of Harvard. His brother, Evan Bebb, became a business man in New York City. The firm of Bebb and Graham preceded the pioneer department store, A. T. Stewart and Company.

OTHER NATIONALLY KNOWN MEN

The Paddy's Run community did not stop when it produced a native born governor of Ohio.

Governor James Brown Ray of Indiana, born in Jefferson County, Kentucky, 1794, attended school in Paddy's Run, probably living across the line in Franklin County, Indiana. He studied law in Cincinnati, was the last non-partisan governor ever elected anywhere in the United States as far as I know.

He advocated railroads running like spokes of a wheel out from Indianapolis. He served from 1825 to 1831. He died of cholera in Cincinnati in 1848.

There have been a number of noted ministers. Rev. Benjamin W. Chidlaw, born in Wales, graduate of the class of 1833 of Miami University, began his preaching at Paddy's Run, and then spent fifty years in the service of the Sunday School Union.

Dr. Thomas Ebenezer Thomas graduated at Miami in 1834. He was a member of the first anti-slavery group in Butler County, and became a well known Abolitionist. He was for some years president of Hanover College in Indiana, and then professor in The New Albany Theological Seminary. This school was moved to Chicago as McCormick Seminary and Dr. Thomas was dropped with others because of their radical views on the subject of slavery. He was a Moderator of a Presbyterian General Assembly and died in harness while teaching in the Lane Theological Seminary, in Cincinnati.

Dr. Mark Williams, Miami '58, was a missionary to North China for fifty-four years, having been sent out when the route to China was by sailing vessel eastward around the Cape of Good Hope rather than westward across the Pacific by steamer.

Among writers Paddy's Run has made notable contribution in the persons of Murat Halstead and Albert Shaw.

Murat Halstead, from whom I quoted the description of the valley, was a student at Farmer's College, a war correspondent, the editor of the Cincinnati Commercial for many years, and of the Brooklyn Graphic.

Albert Shaw, still living at the age of 84, graduated from Grinnell College, Iowa, was the editor of the Minneapolis Tribune from 1883–1888, and 1889–90, was appointed professor of government and international law in Cornell University, 1890, and established the American Review of Reviews in 1891. He is the author of many economic and contemporary history studies.

I will end with the mention of two brothers, descendants of David and Mary Francis, of the group of passengers on the *Maria* in 1795, who are also grandnephews of Governor Bebb.

Mark Francis, O. S. U. '87, was professor of veterinary medicine in the Texas A. and M. College. He devised a method of immunizing cattle against the tick fever, and so made possible the development of the great cattle industry of the Southwest.

President Thompson, speaking about 1915, said of him, the first graduate of the Ohio State veterinary school, that if the Ohio State University during the forty odd years of its existence had done nothing but give Mark Francis to the world, it would have earned all it had cost the state of Ohio up to that time.

Edward Francis, O. S. U. 1894, Public Health Surgeon, is retired, but still at work in the Hygienic laboratory in Washington.

He is known among his colleagues as the human test tube, because he has suffered from so many of the diseases he has worked with. He is best known for his very complete studies of Tularemia or Rabbit Fever, numerous publications from 1919 on. The Rocky Mountain Spotted Fever, the Undulant Fever, the Tick or Relapsing Fever are other diseases his work has helped to understand.

I am sad to have to report that due to centralization of the public schools and mail coming from Hamilton by rural free delivery, there may be nothing left of the village on the Paddy's Run, which has produced more than 250 college graduates, but the crossroads. However the stock, whether Welsh, early American, or German, is still surviving, scattered over our 48 states, and should continue to give a good account of itself.

Statistical Methods

The third edition of this excellent text should receive the same favorable response accorded to the previous two editions, formerly reviewed in this Journal. New material in the third edition includes a chapter on the design and analysis of samplings, new illustrations of various transformations, tests for homogeneity of variance in groups which may have unequal numbers of items, and the analysis of variance in regression. The new edition is under the imprint of the Iowa State College Press and is beautifully bound and printed.—*L. H. S*

Statistical Methods, by George W. Snedecor. xiii + 42 pp. Ames, the Iowa State College Press. 1940. $3.75.

Shull's "Animal Biology"

The plan and nature of this standard text-book remain the same. The revision, however, is quite evident in several chapters. The function of structures receives considerably more attention and all physiological data are modernized. The chapter on embryology has been reorganized and simplified and the one on classification has been enlarged by the inclusion of some general information about each phylum. The size and general appearance of the book have not been changed.—*Carl Venard.*

Principles of Animal Biology, by A. Franklin Shull. xiv + 417 pp. 298 figs. 5th edition. New York, McGraw-Hill Book Co. 1941. $3.50.

ADDITIONS TO THE REVISED CATALOGUE OF OHIO VASCULAR PLANTS. IX*

CLYDE H. JONES

During the past year approximately 4,000 sheets have been added to the State Herbarium. This constant and widespread interest in the vegetation of the state is quite gratifying, since it is from the unified efforts of the professional and amateur botanists that our knowledge of plant distribution and migration is augmented.

Approximately 1,500 sheets have been added to the General Herbarium. This addition comprises collections from California and Nevada by A. M. Wallace; and the Salt Pond Mountain of Virginia, Bear Tooth Mountains of Montana, Wind River Mountains of Wyoming, and northern Ontario collections of the author.

Through the combined efforts of N.Y.A. students, and students of the Botany Department, a rather extensive project consisting of poisoning, mounting, and the preparing of new labels and genus covers for all specimens housed in both the State and General Herbarium has been brought to a successful termination.

In addition to the above project an herbarium of woody twigs in dormant condition has just been completed. This collection should be of value to students who wish to check their future identifications of twigs in winter.

Rapid changes in world industry and transportation during the past few months have revived an active interest in native medicinal plants and their cultivation. A project to map the distribution of all plants of known medicinal value and assemble data on their habitat requirements is now under way.

The following list of additions represent new county or state records.

8. *Osmunda regalis* L. Royal-fern. Bidwell, Gallia Co. Clyde H. Jones.
27. *Asplenium montanum* Willd. Mountain Spleenwort. Nile Twp., Scioto Co. Floyd B. Chapman.
30. *Athyrium angustum* (Willd.) Presl. Upland Lady-fern. Ridge Twp., Van Wert Co. M. B. Overholt. Waverly-Peck Rd., Pike Co. Gordon S. Crowl.
35. *Dryopteris cristata* (L.) Gr. Crested Shield-fern. Bidwell, Gallia Co. Clyde H. Jones.

---

*Papers from the Department of Botany, The Ohio State University, No. 437.

38. *Dryopteris marginalis* (L.) Gr. Marginal Shield-fern. Mohican Dam, Coshocton Co. W. G. Stover.
42. *Polystichum acrostichoides* (Mx.) Schott. Christmas-fern. Knox Co. L. E. Yarman.
45. *Cystopteris fragilis* (L.) Bernh. Fragile Bladder-fern. Ridge Twp., Van Wert Co. M. B. Overholt. Jackson Twp., Perry Co. William Goslin.
53. *Equisetum laevigatum* A. Br. Smooth Scouring-rush. Paxton Twp., Ross Co. Floyd Bartley and Leslie L. Pontius.
55. *Equisetum kansanum* Schaffn. Kansas Scouring-rush. Clyde, Sandusky Co. W. G. Stover.
59. *Equisetum fluviatile* L. Water Horsetail. Harmony Twp., Clark Co. Edward S. Thomas.
61. *Equisetum arvense* L. Field Horsetail. Berne Twp., Fairfield Co. Robert Goslin.
70. *Picea abies* (L.) Karst. Norway Spruce. Planted. Prichard Hollow, Ross Co. Gordon S. Crowl.
73. *Pinus strobus* L. White Pine. Planted. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.
77. *Thuja occidentalis* L. American Arborvitae. Union Co. B. F. DeHays.
79. *Juniperus virginiana* L. Red Juniper. Adams and Scioto Co. Clyde H. Jones.
81. *Taxus canadensis* Marsh. American Yew. Hanover Twp., Richland Co. John H. Schaffner.
94. *Potamogeton americanus* Cham. & Schl. Long-leaf Pondweed. Tiverton Twp., Coshocton Co. F. B. Selby.
117. *Castalia odorata* (Dry.) W. & W. Sweet-scented Water-lily. Buckeye Lake, Fairfield Co. William Goslin.
119. *Philotria canadensis* (Mx.) Britt. Common Water-weed. Tiverton Twp., Coshocton Co. F. B. Selby.
120. *Vallisneria spiralis* L. Tape-grass. Tuscarawas Twp., Coshocton Co. F. B. Selby.
125. *Typha latifolia* L. Broad-leaf Cat-tail. Berne Twp., Fairfield Co. William Goslin.
126. *Typha angustifolia* L. Narrow-leaf Cat-tail. McArthur, Vinton Co. Clyde H. Jones.
127. *Acorus calamus* L. Sweet-flag. Garrettsville, Portage Co. Don M. Brown. Hocking Twp., Fairfield Co. William Goslin.
129. *Spathyema foetida* (L.) Raf. Skunk-cabbage. Pleasant Twp., Fairfield Co. William Goslin.
131. *Arisaema dracontium* (L.) Schott. Green-dragon. Ridge Twp., Van Wert Co. M. B. Overholt. Adams and Scioto Co. Clyde H. Jones.
132. *Arisaema triphyllum* (L.) Torr. Jack-in-the-pulpit. Ridge Twp., Van Wert Co. M. B. Overholt.
143. *Scirpus atrovirens* Muhl. Dark-green Bulrush. Charm, Holmes Co. Don M. Brown.
154. *Fimbristylis autumnalis* (L.) R. & S. Slender Fimbristylis. Scioto Co. Conrad Roth and Floyd B. Chapman. Huntington Twp., Gallia Co. Clyde H. Jones.
157. *Eleocharis compressa* Sull. Flat-stemmed Spike-rush. Adams Co. Floyd Bartley and Leslie L. Pontius.
166. *Stenophyllus capillaris* (L.) Britt. Hair-like Stenophyllus. Scioto Co. Floyd B. Chapman.
168. *Cyperus strigosus* L. Straw-colored Cyperus. Huntington Twp., Gallia Co. Clyde H. Jones.
178. *Cyperus flavescens* L. Yellow Cyperus. Brady Lake, Portage Co. Don M. Brown.
195. *Carex rosea* Schk. Stellate Sedge. Clarkson, Columbiana Co. Don M. Brown.
217. *Carex trisperma* Dew. Three-fruited Sedge. Ashland Co. Floyd Bartley and Leslie L. Pontius.
226. *Carex incomperta* Bickn. Prickly Bog Sedge. Bidwell, Gallia Co. Clyde H. Jones.

228. *Carex scoparia* Schk. Pointed Broom Sedge. Perry Twp., Stark Co. Don M. Brown.
229. *Carex tribuloides* Wahl. Blunt Broom Sedge. Phalanx Mills, Trumbull Co. and Perry Twp., Stark Co. Don M. Brown.
249. *Carex gynandra* Schw. Nodding Sedge. Brown Twp., Carroll Co. Don M. Brown.
250. *Carex crinita* Lam. Fringed Sedge. Clarkson, Columbiana Co. and Canton Twp., Stark Co. Don M. Brown. Bidwell, Gallia Co. Clyde H. Jones.
318. *Carex squarrosa* L. Squarrose Sedge. Canton Twp., Stark Co. Don M. Brown.
326. *Bromus kalmii* Gr. Kalm's Chess. Deercreek Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.
328. *Bromus secalinus* L. Common Chess. Greenville, Darke Co. Dale W. Jenkins.
332. *Bromus inermis* Leyss. Hungarian Brome-grass. Hamburg, Fairfield Co.
334. *Bromus purgans* L. Hairy Brome-grass. Deercreek Twp., Pickaway Co. Leslie L. Pontius and Floyd Bartley.
340. *Festuca nutans* Willd. Nodding Fescue-grass. Dayton, Montgomery Co. Alfred Lonsing.
342. *Festuca ovina* L. Sheep Fescue-grass. Cedar Falls, Adams Co. Floyd Bartley and Leslie L. Pontius.
344. *Festuca octoflora* Walt. Slender Fescue-grass. Scioto Co. Glenn W. Blaydes.
353. *Uniola latifolia* Mx. Broad-leaf Spike-grass. Franklin Co. W. G. Dore.
362. *Poa pratensis* L. Kentucky Blue-grass. Ridge Twp., Van Wert Co. M. B. Overholt.
366. *Eragrostis pectinacea* (Mx.) Steud. Purple Love-grass. Franklin Co. W. G. Dore.
367. *Eragrostis hypnoides* (Lam.) B. S. P. Creeping Love-grass. Green Twp., Scioto Co. Floyd B. Chapman and Conrad Roth.
368. *Eragrostis major* Host. Strong-scented Love-grass. Pleasant Twp., Clark Co. Clyde H. Jones.
373. *Eragrostis capillaris* (L.) Ness. Capillary Love-grass. Adams Co. Floyd Bartley and Leslie L. Pontius.
378. *Korycarpus arundinaceus* Zea. American Korycarpus. Hocking Co. W. G. Dore.
379. *Tridens flava* (L.) Hitchc. Tall Purple-top. Hocking Co. W. G. Dore.
383. *Danthonia spicata* (L.) Beauv. Common Wild-oat-grass. Franklin Co. W. G. Dore. Deercreek Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.
397. *Sporobolus asper* (Mx.) Kunth. Longleaf Rush-grass. Lancaster, Fairfield Co. Elida, Allen Co.
415. *Phleum pratense* L. Timothy. Ridge Twp., Van Wert Co. M. B. Overholt.
429. *Aristida oligantha* Mx. Few-flowered Triple-awned-grass. Cedar Grove, Hocking Co. W. G. Stover. Mt. Vernon, Knox Co. Eugene Good.
447. *Elymus striatus* Willd. Slender Wild-rye. Franklin Co. W. G. Dore.
452. *Hordeum jubatum* L. Squirrel-tail Barley. Ridge Twp., Van Wert Co. M. B. Overholt.
453. *Spartina michauxiana* Hitchc. Tall Slough-grass. Warren Co.Floyd Bartley and Leslie L. Pontius. Mt. Vernon, Knox Co. Eugene Good.
471. *Panicum capillare* L. Trumble Panic-grass. Adams Co. Clyde H. Jones.
474. *Panicum depauperatum* Muhl. Starved Panic-grass. Knox Co. Eugene Good.
476. *Panicum scribnerianum* Nash. Scribner's Panic-grass. Pleasant Twp., Clark Co. Clyde H. Jones.
479. *Panicum linearifolium* Scribn. Linear-leaf Panic-grass. Franklin Co. W. G. Dore.
482. *Panicum sphaerocarpon* Ell. Round-fruited Panic-grass. Deercreek Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.
486.1. *Panicum barbulatum* Michx. Scioto Co. Clyde H. Jones.
490. *Panicum tsugetorum* Nash. Hemlock Panic-grass. Plain Twp., Stark Co. Don M. Brown.

491. *Panicum villosissimum* Nash. Villous Panic-grass. Deercreek Twp., Pickaway Co. and Warren Co. Floyd Bartley and Leslie L. Pontius.
495. *Panicum commutatum* Schultes. Variable Panic-grass. Scioto Co. Clyde H. Jones.
497. *Panicum latifolium* L. Broad-leaf Panic-grass. Hocking Co. W. G. Dore.
498. *Panicum boscii* Poir. Bosc's Panic-grass. Ross-Hocking Park, Ross Co. and Vinton Co. William Goslin. Scioto Co. Clyde H. Jones.
499. *Leptoloma cognatum* (Schultes) Chase. Fall Witch-grass. Ashtabula Co. W. G. Dore.
503. *Echinochloa crus-galli* (L.) Beauv. Common Barnyard-grass. Canton Twp., Stark Co. Don M. Brown.
510. *Chaetochloa viridis* (L.) Scribn. Green Foxtail-grass. Knox Co. L. E. Yarman.
512. *Chaetochloa glauca* (L.) Scribn. Yellow Foxtail-grass. Franklin Co. W. G. Dore.
512.1. *Pennisetum alopecuroides* (L.) Spreng. Franklin Co. W. G. Dore. Brookville, Montgomery Co. Delzie Demaree.
516. *Sorghastrum nutans* (L.) Nash. Indian-grass. Logan Co. Pleasant Twp., Clark Co. Clyde H. Jones.
519. *Andropogon furcatus* Muhl. Big Bluestem. Pleasant Twp., Clark Co. Clyde H. Jones.
522. *Andropogon scoparius* Mx. Little Bluestem. Black Lake, Logan Co. Cutler, Athens Co. W. P. Porter and P. S. Wamsley.
526. *Lilium superbum* L. Turk's-cap Lily. Jackson Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.
527. *Lilium canadense* L. Canada Lily. Knox Co.. Katie M. Roads. Warren Co. Floyd Bartley and Leslie L. Pontius. Washington Twp., Van Wert Co. M. B. Overholt.
533.1. *Hosta caerulea* Tratt. Common Plantain-lily. Auglaize Co. William Kayser.
534. *Allium tricoccum* Ait. Wild Leek. Adams Co. Floyd Bartley and Leslie L. Pontius.
535. *Allium vineale* L. Field Garlic. Lancaster, Fairfield Co. Robert Goslin.
538. *Allium canadense* L. Meadow Garlic. Cliff Creek, Ross Co. Gordon S. Crowl.
539. *Allium cernuum* Roth. Nodding Onion. Scioto Co. Clyde H. Jones.
541. *Quamasia hyacinthina* (Raf.) Britt. Wild Hyacinth. Oxford Twp., Tuscarawas Co. Floyd Von Ohlen.
544. *Ornithogalum umbellatum* L. Star-of-Bethlehem. Berne Twp., Fairfield Co. Robert Goslin.
547. *Aletris farinosa* L. Colic-root. Liberty and Plain Twps., Wood Co. R. E. Shanks.
551. *Anticlea elegans* (Pursh) Rydb. Glaucous Anticlea. Mantua, Portage Co. Don M. Brown.
552. *Stenanthium robustum* Wats. Stout Stenanthium. Gallia Co. Floyd Bartley and Leslie L. Pontius.
563. *Uvularia sessilifolia* L. Sessile-leaf Bellwort. Omega, Pike Co. Gordon S. Crowl. Warwick Twp., Tuscarawas Co. Irma Nelson.
564. *Uvularia perfoliata* L. Perfoliate Bellwort. Adams and Scioto Co. Clyde H. Jones.
565. *Uvularia grandiflora* Sm. Large-flowered Bell-wort. Hocking Twp., Fairfield Co. William Goslin.
569. *Polygonatum commutatum* (R. & S.) Dietr. Smooth Solomon's-seal. Hocking Co. B. F. DeHays.
572. *Vagnera stellata* (L.) Mor. Stellate False Solomon's-seal. Ridge Twp., Van Wert Co. M. B. Overholt.
574. *Unifolium canadense* (Desf.) Greene. False Lily-of-the-valley. Coshocton Co. F. B. Selby.
578. *Asparagus officinalis* L. Asparagus. Ridge Twp., Van Wert Co. M. B. Overholt. Greenfield Twp., Fairfield Co. William Goslin.
580. *Smilax herbacea* L. Common Carrion-flower. Ridge Twp., Van Wert Co. M. B. Overholt. Berne Twp., Fairfield Co. William Goslin.
583. *Smilax hispida* Muhl. Hispid Greenbrier. Pike Co. Gordon S. Crowl.

584. *Smilax rotundifolia* L. Round-leaf Greenbrier. Ridge Twp., Van Wert Co. M. B. Overholt.
588. *Tradescantia virginiana* L. Virginia Spiderwort. Berne Twp., Fairfield Co. William Goslin.
590. *Commelina communis* L. Asiatic Day-flower. Pike Co. Gordon S. Crowl.
597.2. *Juncus secundus* Beuv. Secund Rush. Perry Twp., Shelby Co., and Neotoma, Hocking Co. R. E. Shanks.
597.3. *Juncus vaseyi* Engelm. No record. Correction made by R. E. Shanks.
598. *Juncus bufonius* L. Toad Rush. Scioto Co. Floyd B. Chapman and Conrad Roth.
614. *Xyris flexuosa* Muhl. Slender Yellow-eyed-grass. Madison Twp., Scioto Co. Floyd B. Chapman.
625. *Sisyrinchium albidum* Raf. White Blue-eyed-grass. Pleasant Twp., Clark Co. Clyde H. Jones.
633. *Iris cristata* Ait. Crested Dwarf Iris. Gallia Co. A. C. Priestly.
639. *Galeorchis spectabilis* (L.) Rydb. Showy Orchis. Winesburg, Holmes Co. Don M. Brown.
654. *Ibidium cernuum* (L.) House. Nodding Lady's-tresses. Monroe Twp., Coshocton Co. F. B. Selby. Greenfield Twp., Fairfield Co. Robert Goslin.
657. *Ibidium praecox* (Walt.) House. Grass-leaf Lady's-tresses. Mt. Vernon, Knox Co. Eugene Good.
658. *Ibidium gracile* (Bigel.) House. Slender Lady's-tresses. La Fayette Twp., Coshocton Co. F. B. Selby.
673. *Corallorrhiza wisteriana* Conrad. Wister's Coral-root. Polk Hollow, Adams Co. Floyd Bartley and Leslie L. Pontius. Greenfield Twp., Fairfield Co. Robert Goslin.
678. *Magnolia acuminata* L. Cucumber Magnolia. Hocking Twp., Fairfield Co. Robert Goslin.
680. *Asimina triloba* (L.) Dunal. Papaw. Ridge Twp., Van Wert Co. M. B. Overholt. Garrettsville, Portage Co. Don M. Brown.
681. *Ranunculus abortivus* L. Kidney-leaf Crowfoot. Ridge Twp., Van Wert Co. M. B. Overholt.
682. *Ranunculus micranthus* Nutt. Rock Crowfoot. Pleasant Twp., Fairfield Co. Robert Goslin.
683. *Ranunculus sceleratus* L. Celery-leaf Crowfoot. Berne Twp., Fairfield Co. Robert Goslin.
684. *Ranunculus recurvatus* Poir. Hooked Crowfoot. Ross Co. Floyd Bartley and Leslie L. Pontius.
687. *Ranunculus acris* L. Tall Buttercup. Lancaster, Fairfield Co. William Goslin.
697. *Batrachium trichophyllum* (Chaix.) Schultz. White Water-crowfoot. Green Twp., Ross Co. Floyd Bartley and Leslie L. Pontius.
698. *Batrachium circinatum* (Sibth.) Rchb. Circinate White Water-crowfoot. Muskingum Co. Floyd Von Ohlen.
713. *Anemone quinquefolia* L. Wind-flower. Monroe Twp., Coshocton Co. F. B. Selby.
715. *Hepatica acutiloba* DC. Sharp-lobed Liver-leaf. Goodhope Twp., Hocking Co. William Goslin.
720. *Hydrastis canadensis* L. Golden-seal. Hocking Co. William Goslin.
722. *Actaea alba* (L.) Mill. White Baneberry. Loudenville, Ashland Co. Don M. Brown. Hospital Grounds, Athens, Athens Co. Warren Abbott.
728. *Thalictrum polygamum* Muhl. Tall Meadow-rue. Lawrence Twp., Tuscarawas Co. and Sugar Creek Twp., Stark Co. Don M. Brown.
734. *Berberis thunbergii* DC. Japanese Barberry. Escaped in Stark Co. Ted Grisez.
734.1. *Berberis ottawensis* Schneck. (*B. thunbergii* x *B. vulgaris*) Camden, Preble Co. Olivia Hambleton.
736. *Jeffersonia diphylla* (L.) Pers. Twinleaf. Union Co. B. F. DeHays.
737. *Podophyllum peltatum* L. May-apple. Ridge Twp., Van Wert Co. M. B. Overholt. Hocking Co. B. F. DeHays. Berne Twp., Fairfield Co. William Goslin.

738. *Menispermum canadense* L. Moonseed. Berne Twp., Fairfield Co. William Goslin. Union Co. B. F. DeHays.
745. *Papaver rhoeas* L. Field Poppy. Berne Twp., Fairfield Co. William Goslin.
750. *Sanguinaria canadensis* L. Bloodroot. Berne Twp., Fairfield Co. William Goslin.
754. *Bicuculla cucullaria* (L.) Millsp. Dutchman's-breeches. Ridge Twp., Van Wert Co. M. B. Overholt. Berne Twp., Fairfield Co. William Goslin. Athens, Athens Co. Warren Abbott.
755. *Bicuculla canadensis* (Goldie) Millsp. Squirrel-corn. Athens, Athens Co. Warren Abbott.
756. *Adlumia fungosa* (Ait.) Greene. Climbing Fumitory. Tiverton Twp., Coshocton Co. F. B. Selby.
765. *Draba verna* L. Vernal Whitlow-grass. Pleasant Twp., Fairfield Co. William Goslin.
770. *Camelina microcarpa* Andrz. Small-fruited False-flax, Ross Co. Floyd Bartley and Leslie L. Pontius. Tiverton Twp., Coshocton Co. F. B. Selby. Berne Twp., Fairfield Co. William Goslin.
771. *Bursa bursa-pastoris* (L.) Britt. Shepherd's-purse. Lancaster, Fairfield Co. William Goslin. Athens, Athens Co. Warren Abbott.
773. *Armoracia armoracia* (L.) Britt. Horseradish. Berne Twp., Fairfield Co. William Goslin.
777. *Radicula palustris* (L.) Moench. Marsh Yellow-cress. Berne Twp., Fairfield Co. William Goslin.
779. *Lepidium campestre* (L.) R. Br. Field Peppergrass. Washington Co. C. J. Willard. Ridge Twp., Van Wert Co. M. B. Overholt.
783. *Lepidium densiflorum* Schrad. Wild Peppergrass. Phalanx Mills, Trumbull Co. Don M. Brown.
796. *Erysimum officinale* L. Hedge-mustard. Berne Twp., Fairfield Co. William Goslin. Marion Prairie, Marion Co. Clyde H. Jones.
797. *Norta altissima* (L.) Britt. Tall Hedge-mustard. Berne Twp., Fairfield Co. Robert Goslin.
802. *Barbarea vulgaris* R. Br. Yellow Winter-cress. Ridge Twp., Van Wert Co. M. B. Overholt. Berne Twp., Fairfield Co. William Goslin.
805. *Iodanthus pinnatifidus* (Mx.) Steud. Purple Rocket. Berne Twp., Fairfield Co. William Goslin. Adams and Scioto Co. Clyde H. Jones.
810. *Arabis laevigata* (Muhl.) Poir. Smooth Rock-cress. Madison Co. A. E. Waller and J. N. Wolfe. Pleasant Twp., Fairfield Co. Robert Goslin.
811. *Arabis canadensis* L. Sickle-pod Rock-cress. Berne Twp., Fairfield Co. William Goslin. Feightner Church, Ross Co. Gordon S. Crowl.
816. *Cardamine douglassii* (Torr.) Britt. Purple Bitter-cress. Pleasant Twp., Fairfield Co William Goslin.
817. *Cardamine bulbosa* (Schreb.) B. S. P. Bulbous Bitter-cress Pleasant Twp., Clark Co. Clyde H. Jones
832. *Sinapis arvensis* L. Corn Mustard. Berne Twp., Fairfield Co. Robert Goslin.
837. *Brassica napus* L. Rape. Lancaster, Fairfield Co. William Goslin.
843. *Polanisia graveolens* Raf. Clammy-weed. Paris Twp., Stark Co. Don M. Brown.
848. *Geranium maculatum* L. Wild Crane's-bill. Ridge Twp., Van Wert Co. M. B. Overholt.
854. *Robertiella robertiana* (L.) Hanks. Herb-Robert. Lawrence Twp., Tuscarawas Co. Don M. Brown.
856. *Oxalis grandis* Small. Great Wood-sorrel. Ridge Twp., Van Wert Co. M. B. Overholt. Vinton Co. William Goslin.
857. *Oxalis stricta* L. Upright Wood-sorrel. Lancaster, Fairfield Co. William Goslin.
868. *Linum virginianum* L. Virginia Flax. Madison Twp., Fairfield Co. Edward S. Thomas, Gene and Helen Rea.
873. *Impatiens biflora* Walt. Spotted Touch-me-not. Ridge Twp., Van Wert Co. M. B. Overholt. Rockbridge, Hocking Co. William and Robert Goslin.
874. *Impatiens pallida* Nutt. Pale Touch-me-not. Berne Twp., Fairfield Co. William and Robert Goslin.

876. *Zanthoxylum americanum* Mill. Prickly-ash. Union Co. B. F. DeHays.
881. *Polygala senega* L. Seneca Snakeroot. Scioto Co. Clyde H. Jones.
882. *Polygala viridescens* L. Purple Milkwort. La Fayette Twp., Coshocton Co. F. B. Selby.
888. *Acalypha virginica* L. Virginia Three-seeded Mercury. Berne Twp., Fairfield Co. Robert Goslin.
889. *Acalypha gracilens* Gr. Slender Three-seeded Mercury. Greenfield Twp., Fairfield Co. Robert Goslin.
891. *Croton capitatus* Mx. Capitate Croton. Green Twp., Adams Co. Edward S. Thomas.
892. *Croton monanthogynus* Mx. Single-fruited Croton. Meigs Co. Conrad Roth.
895. *Poinsettia dentata* (Mx.) Small. Toothed Spurge. New Castle Twp., Coshocton Co. F. B. Selby. Berne Twp., Fairfield Co. Robert Goslin. Pleasant Twp., Clark Co. Clyde H. Jones.
905. *Tithymalopsis corollata* (L.) Kl. & Garcke. Flowering Spurge. Marion Prairie. Marion Co. Clyde H. Jones.
906. *Euphorbia marginata* Pursh. Snow-on-the-mountain. Escaped in Louisville, Stark Co. Ted Grisez.
912. *Chamaesyce serpens* (H. B. K.) Small. Roundleaf Spurge. Marion Prairie, Marion Co. Clyde H. Jones.
914. *Callitriche heterophylla* Pursh. Larger Water-starwort. Clark Twp., Coshocton Co. F. B. Selby. Perry Twp., Stark Co. Don M. Brown.
917. *Malva rotundifolia* L. Roundleaf Mallow. Lancaster, Fairfield Co. William Goslin.
924. *Sida hermaphrodita* (L.) Rusby. Tall Sida. Adams Co. Conrad Roth.
926. *Abutilon abutilon* (L.) Rusby. Velvet-leaf. Berne Twp., Fairfield Co. William Goslin. Knox Co. L. E. Yarman.
927. *Hibiscus syriacus* L. Shrubby Hibiscus. Knox Co. L. E. Yarman.
930. *Hibiscus militaris* Cav. Halberd-leaf Rose-mallow. Napoleon, Henry Co. Floyd B. Chapman.
931. *Hibiscus trionum* L. Bladder Ketmia. Ridge Twp., Van Wert Co. M. B. Overholt. Berne Twp., Fairfield Co. William and Robert Goslin.
934. *Tilia heterophylla* Vent. White Linden. Ross and Jackson Co. Floyd Bartley and Leslie L. Pontius. Adams Co. Robert B. Gordon and Arthur Harper. Monroe Co. W. A. Kellerman.
937. *Hypericum prolificum* L. Shrubby St. John's-wort. Muskingum Co. Floyd Von Ohlen.
939. *Hypericum perforatum* L. Common St. John's-wort. Hocking Twp., Fairfield Co. William Goslin.
940. *Hypericum punctatum* Lam. Spotted St. John's-wort. Athens, Athens Co. Warren Abbott. Knox Co. L. E. Yarman.
943. *Hypericum boreale* (Britt.) Bickn. Northern St. John's-wort. Wingfoot Lake, Portage Co. Don M. Brown.
963. *Viola canadensis* L. Canada Violet. Salt Creek, Ross Co. Gordon S. Crowl. Adams Co. Clyde H. Jones.
967. *Viola striata* Ait. Striped Violet. Pleasant Twp., Van Wert Co. M. B. Overholt.
968. *Viola conspersa* Reich. American Dog Violet. Cedar Swamp, Champaign Co. Edward S. Thomas.
970. *Viola rostrata* Pursh. Long-spurred Violet. Goodhope Twp., Hocking Co. William Goslin.
978. *Viola cucullata* Ait. Marsh Blue Violet. Pleasant Twp., Clark Co. Clyde H. Jones.
979. *Viola affinis* LeC. Thinleaf Blue Violet. Neotoma, Hocking Co. Edward S. Thomas. Clifton Gorge, Green Co. C. F. Walker and J. W. Sites.
981. *Viola sororia* Willd. Woolly Blue Violet. Hocking Twp., Fairfield Co. Robert Goslin. Ridge Twp., Van Wert Co. M. B. Overholt.
984. *Viola palmata* L. Early Blue Violet. Hocking Twp., Fairfield Co. William Goslin.
988. *Viola sagittata* Ait. Arrow-leaf Violet. Kettle Hills, Fairfield Co. Robert Goslin. Marion Prairie, Marion Co. Clyde H. Jones.
1001. *Alsine media* L. Common Chickweed. Berne Twp., Fairfield Co. William Goslin.

1002. *Alsine pubera* (Mx.) Britt. Great Chickweed. Salt Creek, Ross Co. Gordon S. Crowl. Ridge Twp., Van Wert Co. M. B. Overholt.

1010. *Cerastium longipedunculatum* Muhl. Nodding Chickweed. Berne Twp., Fairfield Co. William Goslin. Madison Co. A. E. Waller and J. N. Wolfe. Scioto Co. Clyde H. Jones.

1015. *Lychnis alba* Mill. White Lychnis. Berne Twp., Fairfield Co. William Goslin.

1020. *Silene latifolia* (Mill.) Britt. & Rend. Bladder Campion. Berne Twp., Fairfield Co. William Goslin.

1031. *Silene antirrhina* L. Sleepy Catchfly. Kettle Hills, Fairfield Co. William Goslin.

1032. *Saponaria officinalis* L. Bouncing-Bet. Knox Co. L. E. Yarman.

1035. *Dianthus armeria* L. Deptford Pink. Berne Twp., Fairfield Co. William Goslin. Adams Co. Clyde H. Jones.

1038. *Claytonia virginica* L. Spring-beauty. Lancaster, Fairfield Co. William Goslin. Ridge Twp., Van Wert Co. M. B. Overholt.

1043. *Phytolacca americana* L. Pokeweed. Berne Twp., Fairfield Co. William Goslin. Ridge Twp., Van Wert Co. M. B. Overholt.

1044. *Allionia nyctaginea* Mx. Heart-leaf Umbrella-wort. Canton Twp., Stark Co. Don M. Brown.

1051. *Amaranthus retroflexus* L. Rough Pigweed. Marion Prairie, Marion Co. Clyde H. Jones.

1052. *Amaranthus hybridus* L. Slender Pigweed. Lancaster, Fairfield Co. Robert Goslin.

1080. *Steironema ciliatum* (L.) Raf. Fringed Yellow Loosestrife. Ridge Twp., Van Wert Co. M. B. Overholt.

1089. *Anagallis arvensis* L. Scarlet Pimpernel. Ross Co. Gordon S. Crowl.

1092. *Dodecatheon meadia* L. Shooting-star. Warren Co. Floyd Bartley and Leslie L. Pontius. Buzzard's Roost, Adams Co. J. P. Steele.

1094. *Rumex verticillatus* L. Swamp Dock. Buckeye Lake, Fairfield Co. William Goslin.

1101. *Rumex crispus* L. Curled Dock. Union Co. B. F. DeHays.

1102. *Rumex acetosella* L. Sheep Sorrel. Franklin Co. Clyde H. Jones. Berne Twp., Fairfield Co. William Goslin.

1103. *Pleuropterus zuccarinii* Small. Japanese Knotweed. Scioto Co. Conrad Roth.

1105. *Tiniaria scandens* (L.) Small. Climbing False Buckwheat. Hocking Twp., Fairfield Co. William Goslin.

1107. *Fagopyrum fagopyrum* (L.) Karst. Buckwheat. Berne Twp., Fairfield Co. William and Robert Goslin.

1109. *Tracaulon arifolium* (L.) Raf. Halberd-leaf Tear-thumb. Scioto Co. Floyd B. Chapman and Conrad Roth. Athens, Athens Co. Walter P. Porter and P. S. Wamsley.

1112. *Persicaria persicaria* (L.) Small. Lady's-thumb. Berne Twp., Fairfield Co. Robert and William Goslin. Ridge Twp., Van Wert Co. M. B. Overholt.

1114. *Persicaria punctata* (Ell.) Small. Dotted Smartweed. Berne Twp., Fairfield Co. William and Robert Goslin.

1115. *Persicaria hydropiper* (L.) Opiz. Water Smartweed. Berne Twp., Fairfield Co. William Goslin.

1117. *Persicaria pennsylvanica* (L.) Small. Pennsylvania Persicaria. Berne Twp., Fairfield Co. William Goslin.

1128. *Geum vernum* (Raf.) T. & G. Spring Avens. Ridge Twp., Van Wert Co. M. B. Overholt. Berne Twp., Fairfield Co. William Goslin.

1129. *Geum canadense* Jacq. White Avens. Pike Co. Gordon S. Crowl.

1130. *Geum virginianum* L. Rough Avens. Pleasant Twp., Fairfield Co. William Goslin.

1132. *Geum strictum* Ait. Yellow Avens. Ridge Twp., Van Wert Co. M. B. Overholt. Tar Hollow, Ross Co. Gordon S. Crowl.

1133. *Dasiphora fruticosa* (L.) Rydb. Shrubby Cinquefoil. Warren Co. Floyd Bartley and Leslie L. Pontius.

1135. *Potentilla monspeliensis* L. Rough Cinquefoil. Tar Hollow, Ross Co. Gordon S. Crowl. Ridge Twp., Van Wert Co. M. B. Overholt.

1136. *Potentilla recta* L. Upright Cinquefoil. Berne Twp., Fairfield Co. Robert Goslin.

1138. *Potentilla canadensis* L. Common Five-finger. Berne Twp., Fairfield Co. William Goslin.

1144. *Waldsteinia fragarioides* (Mx.) Tratt. Dry Strawberry. Lancaster, Fairfield Co. Robert Goslin.

1145. *Fragaria virginiana* Duch. Virginia Strawberry. Bloomfield Twp., Trumbull Co. R. E. Shanks. Lancaster, Fairfield Co. William Goslin. Ross Hollow, Ross Co. Gordon S. Crowl.

1146.1. *Fragaria grayana* Vilmorin. Gray's Strawberry. Dayton, Montgomery Co. Alfred Lonsing.

1148. *Rubus odoratus* L. Rose-flowered Raspberry. Mt. Vernon, Knox Co. Eugene Good.

1150. *Rubus occidentalis* L. Black Raspberry. Berne Twp., Fairfield Co. Ridge Twp., Van Wert Co. M. B. Overholt.

1154. *Rubus frondosus* Bigel. Leafy-flowered Blackberry. Berne Twp., Fairfield Co. William Goslin.

1160. *Porteranthus stipulatus* (Muhl.) Britt. American Ipecac. Berne Twp., Fairfield Co. Edward S. Thomas and Charles E. Walker.

1162. *Filipendula rubra* (Hill.) Rob. Queen-of-the-prairie. Warren Co. Floyd Bartley and Leslie L. Pontius.

1170. *Rosa setigera* Mx. Prairie Rose. Berne Twp., Fairfield Co. William Goslin. Ridge Twp., Van Wert Co. M. B. Overholt. Palestine, Darke Co., Carroll, Carroll Co., Columbus Grove, Putnam Co., Kenton, Hardin Co., Paulding, Paulding Co. W. G. Stover.

1171. *Rosa rubiginosa* L. Sweetbrier. Maumee, Lucas Co. W. G. Stover.

1174. *Rosa blanda* L. Smooth Rose. Scioto Twp., Ross Co. Floyd Bartley and Leslie L. Pontius.

1177. *Rosa carolina* L. Swamp Rose. Rattlesnake Knob, Ross Co. Gordon S. Crowl. Palestine, Darke Co., Cynthiana, Pike Co., Columbiana, Columbiana Co., Maumee, Lucas Co. W. G. Stover.

1178. *Rosa virginiana* Mill. Virginia Rose. Pike Co. Gordon S. Crowl. Sinking Springs, Highland Co., New Philadelphia, Tuscarawas Co., Miller City, Putnam Co., Rome, Franklin Co., Upper Sandusky, Wyandot Co., Columbiana, Columbiana Co., Crawford Co. W. G. Stover.

1179. *Agrimonia parviflora* Sol. Small-flowered Agrimony. Ridge Twp., Van Wert Co. M. B. Overholt.

1194. *Prunus americana* Marsh. Wild Plum. Fairfield Co. Emma A. Ruppersberg.

1199. *Pyrus communis* L. Pear. Louisville, Stark Co. Escaped from cultivation. Ted Grisez.

1206. *Amelanchier canadensis* (L.) Med. Common Juneberry. Berne Twp., Fairfield Co. Robert Goslin.

1215.1. *Crataegus ovatifolia* Sarg. Ashtabula, Ashtabula Co., and Perry, Lake Co. Harry Crofoot and F. J. Tyler.

1219. *Crataegus macrosperma* Ashe. Variable Hawthorn. Lake and Ashtabula Co. Fred J. Tyler and Harry Crofoot.

1223.1. *Crataegus assurgens* Sarg. Harry Crofoot and Fred J. Tyler.

1233. *Gymnocladus dioica* (L.) Koch. Coffee-bean. Knox Co. L. E. Yarman.

1237. *Chamaecrist nictitans* (L.) Moench. Small-flowered Sensitive-pea. Doughty Creek, Holmes Co. Don M. Brown. La Fayette Twp., Coshocton Co. F. B. Selby.

1239. *Baptisia leucantha* T. & G. Large White Wild-indigo. Delaware Co. B. F. DeHays.

1241. *Crotalaria sagittalis* L. Rattlebox. Huntington Twp., Gallia Co. Clyde H. Jones.

1245. *Medicago sativa* L. Alfalfa. Greenfield Twp., Fairfield Co. William Goslin.

1249. *Trifolium procumbens* L. Low Hop Clover. Ridge Twp., Van Wert Co. M. B. Overholt. Goodhope Twp., Hocking Co. Edward S. Thomas and Charles E. Walker.

1253. *Trifolium pratense* L. Red Clover. Lancaster, Fairfield Co. William Goslin.

1256. *Trifolium hybridum* L. Alsike Clover. Knox Co. L. E. Yarman. Tar Hollow, Ross Co. Gordon S. Crowl.

1257. *Trifolium repens* L. White Clover. Berne Twp., Fairfield Co. William Goslin.
1264. *Robinia hispida* L. Rose Acacia. Muskingum Co. Floyd Von Ohlen.
1268.1. *Petalostemum foliosum* A. Gray. Leafy Prairie-clover. Cedar Grove, Hocking Co. W. G. Stover.
1269. *Psoralea onobrychis* Nutt. Sainfoin Psoralea. Adams and Scioto Co. Clyde H. Jones.
1279. *Meibomia paniculata* (L.) Ktz. Panicled Tick-trefoil. Cutler, Athens Co. W. P. Porter and P. S. Wamsley.
1280. *Meibomia canadensis* (L.) Ktz. Canadian Tick-trefoil. Mantua, Portage Co. Don M. Brown.
1282. *Meibomia marylandica* (L.) Ktz. Maryland Tick-trefoil. Cutler, Athens Co. W. P. Porter and P. S. Wamsley.
1287.1. *Meibomia laevigata* (Nutt.) Ktz. Madison Twp., Fairfield Co. Edward S. Thomas, Gene and Helen Rea.
1294. *Lespedeza frutescens* (L.) Britt. Wand-like Bush-clover. Newark, Licking Co. Eugene Good.
1295. *Lespedeza virginica* (L.) Britt. Slender Bush-clover. Lancaster, Fairfield Co. William Goslin.
1297. *Lespedeza repens* (L.) Bart. Creeping Bush-clover. Pleasant Twp., Clark Co. Clyde H. Jones.
1299. *Stylosanthes biflora* (L.) B. S. P. Pencil-flower. Madison Twp., Fairfield Co. Gene Rea.
1300. *Vicia cracca* L. Cow Vetch. Stark Co. Don M. Brown.
1310. *Lathyrus palustris* L. Marsh Pea. Deercreek Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.
1318. *Glycine apios* L. Groundnut. Clark Twp., Coshocton Co. F. B. Selby.
1320. *Falcata pticheri* (T. & G.) Ktz. Pitcher's Hog-peanut. Berne Twp., Fairfield Co. Robert and William Goslin.
1325.1. *Strophostyles umbellata* (Muhl.) Britt. Pink Wild Bean. Richland Co. R. T. Wareham.
1335. *Tiarella cordifolia* L. False Miterwort. Fairfield Co. L. M. Bloomfield.
1338. *Mitella diphylla* L. Two-leaf Bishop's-cap. Goodhope Twp., Hocking Co. William Goslin.
1355. *Rhamnus lanceolata* Pursh. Lance-leaf Buckthorn. Jackson Twp., Perry Co. William Goslin. Pickaway Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.
1363. *Vitis vulpina* L. Riverside Grape. Jackson Twp., Stark Co. Don M. Brown.
1364. *Vitis cordifolia* Mx. Frost Grape. Maumee, Lucas Co. W. G. Stover.
1366. *Parthenocissus quinquefolia* (L.) Planch. Virginia-creeper. Berne Twp., Fairfield Co. William Goslin.
1367. *Euonymus atropurpureus* Jacq. Wahoo. Pickaway Co. William Goslin. Ridge Twp., Van Wert Co. M. B. Overholt.
1370. *Euonymus obovatus* Nutt. Running Strawberry-bush. Johnston Twp., Trumbull Co. R. E. Shanks.
1372. *Celastrus scandens* L. Bitter-sweet. Union Co. B. F. DeHays.
1375. *Ilex verticillata* (L.) Gr. Winterberry. Union Co. B. F. DeHays.
1378. *Aesculus hippovastanum* L. Horse-chestnut. Circleville Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.
1381. *Acer nigrum* Mx. Black Maple. Washington Twp., Richland Co. W. P. Porter and P. S. Wamsley.
1383. *Acer spicatum* Lam. Mountain Maple. Hanover Twp., Richland Co. John H. Schaffner.
1389. *Rhus hirta* (L.) Sudw. Staghorn Sumac. Ridge Twp., Van Wert Co. M. B. Overholt.
1390. *Rhus glabra* L. Smooth Sumac. Ridge Twp., Van Wert Co. M. B. Overholt.
1392. *Toxicodendron vernix* (L.) Ktz. Poison Sumac. Louisville, Stark Co. Ted Grisez.
1393. *Toxicodendron radicans* (L.) Ktz. Poison Ivy. Ridge Twp., Van Wert Co. M. B. Overholt. Greenfield Twp., Fairfield Co. William Goslin.
1395. *Hamamelis virginiana* L. Witch-hazel. Union Co. B. F. DeHays.
1397. *Platanus occidentalis* L. Sycamore. Ridge Twp., Van Wert Co. M. B. Overholt.

1398. *Ulmus americana* L. American Elm. Ridge Twp., Van Wert Co. M. B. Overholt.

1412. *Urtica gracilis* Ait. Slender Nettle. Marion Prairie, Marion Co. Clyde H. Jones. Hocking Twp., Fairfield Co. William Goslin.

1414. *Pilea pumila* (L.) Gr. Clearweed. Pike Co. Gordon S. Crowl.

1415. *Boehmeria cylindrica* (L.) Sw. False Nettle. Clark Twp., Coshocton Co. F. B. Selby. Warren Co. Floyd Bartley and Leslie L. Pontius. Berne Twp., Fairfield Co. William Goslin.

1417. *Fagus grandifolia* Ehrh. American Beech. Ridge Twp., Van Wert Co. M. B. Overholt.

1419. *Quercus muhlenbergii* Engelm. Chestnut Oak. (Yellow Oak). Delaware, Delaware Co. C. R. Wallace.

1421. *Quercus montana* Willd. Rock Chestnut Oak. Five-mile Creek, Pike Co. Gordon S. Crowl.

1422. *Quercus bicolor* Willd. Swamp White Oak. Delaware, Delaware Co. C. R. Wallace.

1425. *Quercus macrocarpa* Mx. Bur Oak. Delaware, Delaware Co. C. R. Wallace.

1426. *Quercus imbricaria* Mx. Shingle Oak. Delaware, Delaware Co. C. R. Wallace. Jackson Twp., Perry Co. William Goslin.

1426a. *Quercus imbricaria* x *velutina* (*Q. leana* Nutt.) Lea's Oak. Tallmadge Twp., Summit Co. Fred H. Glenny.

1430. *Quercus velutina* Lam. Black Oak. Five-mile Creek, Pike Co. Gordon S. Crowl. Delaware, Delaware Co. C. R. Wallace.

1431. *Quercus coccinea* Wang. Scarlet Oak. Ridge Twp., Van Wert Co. M. B. Overholt.

1431.1. *Quercus ellipsoidalis* E. J. Hill. Hill's Oak. Delaware, Delaware Co. C. R. Wallace.

1432. *Quercus borealis* Mx. var. *maxima* (Marsh.) Ashe. Red Oak. Delaware, Delaware Co. C. R. Wallace. Muskingum Co. C. A. Dambach.

1435. *Ostrya virginiana* (Mill.) Willd. Hop-hornbeam. Union Co. B. F. DeHays.

1436. *Corylus americana* Walt. Common Hazelnut. Berne Twp., Fairfield Co. William and Robert Goslin.

1439.2. *Betula populifolia* Marsh. Gray Birch. (Probably escaped from cultivation). Brady Lake, Portage Co. Don M. Brown.

1442. *Alnus incana* (L.) Willd. Hoary Alder. Rattlesnake Knob, Ross Co. Gordon S. Crowl.

1445. *Hicoria pecan* (Marsh.) Britt. Pecan. (Probably escaped from cultivation). Clifton Gorge, Green Co. Floyd Bartley and Leslie L. Pontius.

1452. *Juglans nigra* L. Black Walnut. Pike Co. Gordon S. Crowl.

1453. *Juglans cinerea* L. Butternut. Tar Hollow, Ross Co. Gordon S. Crowl. Ridge Twp., Van Wert Co. M. B. Overholt.

1465. *Salix nigra* Marsh. Black Willow. Adams Co. Clyde H. Jones.

1480. *Salix discolor* Muhl. Pussy Willow. Homeworth, Columbiana Co. Don M. Brown.

1482. *Salix humilis* Marsh. Prairie Willow. Mt. Vernon, Knox Co. Eugene Good.

1495. *Grossularia oxyacanthoides* (L.) Mill. Smooth Gooseberry. Berne Twp., Fairfield Co. William Goslin.

1498. *Ludwigia polycarpa* Short & Peter. Many-fruited Ludwigia. Pitt Twp., Wyandot Co. Edward S. Thomas.

1500. *Isnardia palustris* L. Marsh-purslane. Oxford Twp., Coshocton Co. F. B. Selby. Berne Twp., Fairfield Co. Robert Goslin.

1501. *Chamaenerion angustifolium* (L.) Scop. Fire-weed. Berne Twp., Fairfield Co. Robert Goslin.

1502. *Epilobium lineare* Muhl. Linear-leaf Willow-herb. Madison Twp., Scioto Co. Floyd B. Chapman and Conrad Roth.

1508.1. *Anogra albicaulis* (Pursh) Britt. Prairie Evening-primrose. Introduced in lawn. Athens, Athens Co. W. P. Porter and P. S. Wamsley.

1512. *Kneiffia fruticosa* (L.) Raim. Common Sundrops. Wyandot Co. C. R. Crum and C. J. Willard.

1517. *Circaea lutetiana* L. Common Enchanter's-nightshade. Ridge Twp., Van Wert Co. M. B. Overholt.

1520. *Proserpinaca palustris* L. Mermaid-weed. Warren Co. Floyd Bartley and Leslie L. Pontius. Perry Twp., Stark Co. Don M. Brown.

1530. *Micrampelis lobata* (Mx.) Greene. Wild Balsam-apple. Hocking Twp., Fairfield Co. William Goslin. Putnam Co. M. B. Overholt.

1532. *Asarum canadense* L. Canadian Wild-ginger. Ridge Twp., Van Wert Co. M. B. Overholt.

1543. *Epigaea repens* L. Trailing Arbutus. Braceville Ledge, Trumbull Co. R. E. Shanks.

1579. *Phlox divaricata* L. Wild Blue Phlox. Ridge Twp., Van Wert Co. M. B. Overholt. Cliff Creek, Ross Co. Gordon S. Crowl.

1588. *Convolvulus arvensis* L. Field Bindweed. Berne Twp., Fairfield Co. William Goslin.

1590. *Convolvulus sepium* L. Hedge Bindweed. York Twp., Van Wert Co. M. B. Overholt.

1592. *Convolvulus fraterniflorus* Mack. & Bush. Short-stalked Bindweed. Berne Twp., Fairfield Co. William and Robert Goslin. Putnam Co. M. B. Overholt.

1606. *Phacelia purshii* Buckl. Pursh's Phacelia. Lancaster, Fairfield Co. William Goslin. Canton Twp., Stark Co. Don M. Brown. Pickaway Co. W. G. Stover. Adams and Scioto Co. Clyde H. Jones.

1619. *Fraxinus biltmoreana* Bead. Biltmore Ash. Adams Co. Floyd Bartley and Leslie Pontius.

1625. *Gentiana procera* Holm. Smaller Fringed Gentian. Green Twp., Ross Co. Floyd Bartley and Leslie L. Pontius.

1633. *Obolaria virginica* L. Pennywort. Oxford Twp., Tuscarawas Co. Floyd Von Ohlen.

1639. *Apocynum pubescens* R. Br. Velvet Dogbane. Ridge Twp., Van Wert Co. M. B. Overholt.

1644. *Asclepias tuberosa* L. Pleurisy-root. Greenfield Twp., Fairfield Co. William Goslin.

1645. *Asclepias purpurascens* L. Purple Milkweed. Warren Co. Floyd Bartley and Leslie L. Pontius.

1646. *Asclepias incarnata* L. Swamp Milkweed. Knox Co. L. E. Yarman.

1652. *Asclepias syriaca* L. Common Milkweed. Cedar Grove School, Pickaway Co. R. A. Dobbins. Ridge Twp., Van Wert Co. M. B. Overholt.

1655. *Gonolobus laevis* Mx. Sandvine. Along Tuscarawas River, Coshocton Co. F. B. Selby.

1662. *Datura stramonium* L. Common Jimson-weed. Union Co. B. F. DeHays. Berne Twp., Fairfield Co. Robert Goslin.

1664. *Lycium halimifolium* Mill. Common Matrimony-vine. Berne Twp., Fairfield Co. William Goslin.

1666.1. *Physalis subglabrata* Mack. & Bush. Smooth Ground-cherry. Hocking Twp., Fairfield Co. Robert Goslin.

1667. *Physalis lanceolata* Mx. Prairie Ground-cherry. La Fayette Twp., Coshocton Co. F. B. Selby.

1669. *Physalis virginiana* Mill. Virginia Ground-cherry. Ridge Twp., Van Wert Co. M. B. Overholt.

1676. *Solanum carolinense* L. Horsenettle. Hocking Co. B. F. DeHays. Ridge Twp., Van Wert Co. M. B. Overholt. Fairfield Co. William and Robert Goslin.

1677. *Solanum rostratum* Dunal. Buffalo-bur. Darke Co. D. P. Miller.

1678. *Solanum nigrum* L. Black Nightshade. Cincinnati, Hamilton Co. Couradine Lene.

1682. *Verbascum blattaria* L. Moth Mullen. Ridge Twp., Van Wert Co. M. B. Overholt. Union Co. B. F. DeHays.

1684. *Verbascum thapsus* L. Common Mullen. Ridge Twp., Van Wert Co. M. B. Overholt.

1685. *Pentstemon calycosus* Small. Calycose Beard-tongue. Fort Loramie, Shelby Co. Alfred Lonsing. Bucyrus, Crawford Co. W. G. Stover.

1686. *Pentstemon digitalis* (Sweet) Nutt. Foxglove Beard-tongue. Beldon, Lorain Co. W. G. Stover.

1689. *Pentstemon hirsutus* (L.) Willd. Hairy Beard-tongue. Berne Twp., Fairfield Co. Robert Goslin.

1692. *Chelone glabra* L. Smooth Turtle-head. Madison Twp., Scioto Co. Floyd B. Chapman.
1694. *Scrophularia marylandica* L. Maryland Figwort. La Fayette Twp., Coshocton Co. F. B. Selby.
1702. *Ilysanthes dubia* (L.) Barnh. Short-stalked False Pimpernel. Lawrence Twp., Tuscarawas Co. Don M. Brown.
1711. *Agalinis purpurea* (L.) Penn. Large-flowered Agalinis. Berne Twp., Fairfield Co. Robert Goslin.
1713. *Agalinis tenuifolia* (Vahl.) Raf. Slender Agalinis. Newcastle Twp., Coshocton Co. F. B. Selby.
1726. *Veronica serpyllifolia* L. Thyme-leaf Speedwell. Ridge Twp., Van Wert Co. M. B. Overholt.
1727. *Veronica peregrina* L. Purslane Speedwell. Lancaster, Fairfield Co. William Goslin.
1728. *Veronica arvensis* L. Field Speedwell. Lancaster, Fairfield Co. William Goslin.
1730. *Veronica persica* Poir. Cats-eye Speedwell. Lodi Twp., Athens Co. Harold Moore.
1734. *Pedicularis canadensis* L. Wood Lousewort. Goodhope Twp., Hocking Co. William Goslin.
1735. *Castilleja coccinea* (L.) Spreng. Scarlet Painted-cup. Scioto Co. Clyde H. Jones.
1740. *Chaenorrhinum minus* (L.) Lange. Lesser Toadflax. Paris Twp., Stark Co. Don M. Brown.
1744. *Bignonia radicans* L. Trumpet-creeper. Ridge Twp., Van Wert Co. M. B. Overholt.
1751. *Thalesia uniflora* (L.) Britt. Naked Broom-rape. Berne Twp., Fairfield Co. William Goslin.
1753. *Conopholis americana* (L. f.) Wallr. Squaw-root. Laurel Twp., Hocking Co. Floyd Clum.
1754. *Leptamnium virginianum* (L.) Raf. Beech-drops. Ridge Twp., Van Wert Co. M. B. Overholt. Hocking Co. Floyd Clum.
1755. *Utricularia vulgaris* var. *americana* Gray. Greater Bladderwort. Ottawa Co. Dale W. Jenkins. Warren Co. Floyd Bartley and Leslie L. Pontius. Clark Twp., Coshocton Co. F. B. Selby.
1761. *Ruellia strepens* L. Smooth Ruellia. Pickaway Co. William Goslin.
1769. *Cynoglossum virginianum* L. Wild Comfrey. Greenfield Twp., Fairfield Co. Robert Goslin. Scioto Co. Clyde H. Jones.
1773. *Lithospermum arvense* L. Corn Gromwell. Berne Twp., Fairfield Co. Robert Goslin.
1775. *Lithospermum canescens* (Mx.) Lehm. Hoary Puccoon. Pleasant Twp., Clark Co. Clyde H. Jones.
1780. *Myosotis micrantha* Pall. Small-flowered Forget-me-not. Athens, Athens Co. Walter P. Porter.
1787. *Verbena urticaefolia* L. White Vervain. Berne Twp., Fairfield Co. William Goslin.
1788. *Verbena hastata* L. Blue Vervain. Falls Twp., Hocking Co. Ralph Walker. Berne Twp., Fairfield Co. William Goslin. Knox Co. L. E. Yarman.
1789. *Verbena angustifolia* Mx. Narrowleaf Vervain. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.
1791. *Verbena bracteosa* Mx. Bracted Vervain. Green Twp., Ross Co. Floyd Bartley and Leslie L. Pontius.
1795. *Trichostema dichotomum* L. Blue-curls. Scioto Co. Floyd B. Chapman and Conrad Roth. Pleasant Twp., Clark Co. Clyde H. Jones.
1798. *Teucrium canadense* L. American Germander. Falls Twp., Hocking Co. Ralph Walker. Berne Twp., Fairfield Co. William Goslin.
1805. *Scutellaria pilosa* Mx. Hairy Skullcap. Green Twp., Adams Co. Edward S. Thomas.
1809. *Scutellaria galericulata* L. Marsh Skullcap. Warren Co. Floyd Bartley and Leslie L. Pontius.
1812. *Mentha spicata* L. Spearmint. Falls Twp., Hocking Co. Ralph Walker.
1813. *Mentha piperita* L. Peppermint. Fairfield Co. B. F. DeHays.

1814. *Mentha citrata* Ehrh. Bergamot Mint. Brady Lake, Portage Co. Don M. Brown. Falls Twp., Hocking Co. Ralph Walker.

1822. *Lycopus rubellus* Moench. Stalked Water-hoarhound. Falls Twp., Hocking Co. Ralph Walker.

1824. *Lycopus uniflorus* Mx. Northern Water-hoarhound. Brady Lake, Portage Co. Don M. Brown.

1825. *Perilla frutescens* (L.) Britt. Perilla. Franklin Co. Floyd Clum.

1826. *Collinsonia canadensis* L. Stone-root. Ross Co. Gordon S. Crowl. Also Pike Co.

1828. *Koellia flexuosa* (Walt.) MacM. Narrowleaf Mountain-mint. Knox Co. L. E. Yarman.

1835. *Cunila origanoides* (L.) Britt. American Dittany. Whiskey Run Ridge, Pike Co. Gordon S. Crowl.

1836. *Clinopodium vulgare* L. Field Basil. Falls Twp., Hocking Co. Ralph Walker.

1836.1. *Satureja acinos* (L.) Scheele. Basil Balm. Dayton, Montgomery Co. Alfred Lonsing.

1842. *Agastache nepetoides* (L.) Ktz. Catnip Giant-hyssop. La Fayette Twp., Coshocton Co. F. B. Selby.

1845. *Nepeta cataria* L. Catnip. Knox Co. L. E. Yarman. Pleasant Twp., Fairfield Co. William Goslin. Falls Twp., Hocking Co. Ralph Walker. Ridge Twp., Van Wert Co. M. B. Overholt.

1846. *Glecoma hederacea* L. Ground-ivy. Falls Twp., Hocking Co. Ralph Walker. Berne Twp., Fairfield Co. William Goslin.

1849. *Dracocephalum virginianum* L. Virginia Dragon-head. Goodhope Twp., Hocking Co. William and Robert Goslin. Courtney Hill, Athens Co. W. P. Porter and P. S. Wamsley.

1851. *Stachys palustris* L. Marsh Hedge-nettle. Falls Twp., Hocking Co. Ralph Walker. Greenfield Twp., Fairfield Co. Robert Goslin. Ridge Twp., Van Wert Co. M. B. Overholt.

1853. *Stachys aspera* Mx. Rough Hedge-nettle. York Twp., Van Wert Co. M. B. Overholt.

1854. *Stachys cordata* Ridd. Cordate Hedge-nettle. Tuscarawas Twp., Coshocton Co. F. B. Selby.

1856. *Leonurus cardiaca* L. Common Motherwort. Falls Twp., Hocking Co. Ralph Walker. Greenfield Twp., Fairfield Co. William Goslin.

1857. *Lamium album* L. White Henbit. Franklin Co. A. E. Waller.

1858. *Lamium amplexicaule* L. Common Henbit. Canton Twp., Stark Co. Don M. Brown. Berne Twp., Fairfield Co. Robert Goslin.

1863. *Prunella vulgaris* L. Common Self-heal. Ridge Twp., Van Wert Co. M. B. Overholt. Knox Co. L. E. Yarman. Falls Twp., Hocking Co. Ralph Walker.

1864. *Monarda didyma* L. American Beebalm. Falls Twp., Hocking Co. Ralph Walker. Louisville, Stark Co. Ted Grisez.

1867. *Monarda fistulosa* L. Wild Bergamot. Marion Prairie, Marion Co. Clyde H. Jones. Vinton Co. William Goslin.

1868. *Monarda mollis* L. Canescent Wild Bergamot. Mantua, Portage Co. Don M. Brown. York Twp., Van Wert Co. M. B. Overholt.

1869. *Blephilia ciliata* (L.) Raf. Downy Blephilia. Deercreek Twp., Pickaway Co. Floyd Bartley and Leslie L. Pontius.

1870. *Blephilia hirsuta* (Pursh) Torr. Hairy Blephilia. Berne Twp., Fairfield Co. William Goslin.

1871. *Salvia lyrata* L. Lyreleaf Sage. Adams Co. Clyde H. Jones.

1875. *Salvia officinalis* L. Common Sage. Falls Twp., Hocking Co. Ralph Walker.

1877. *Phryma leptostachya* L. Lopseed. Falls Twp., Hocking Co. Ralph Walker.

1880. *Plantago aristata* Mx. Large-bracted Plantain. Jackson Twp., Perry Co. William Goslin. Lancaster, Fairfield Co. Robert Goslin.

1881. *Plantago purshii* R. & S. Pursh's Plantain. Lucas Co. Floyd Bartley and Leslie L. Pontius.

1882. *Plantago rugelii* Dcne. Rugel's Plantain. Marion Prairie, Marion Co. Clyde H. Jones.

1885. *Plantago virginica* L. Dwarf Plantain. Adams and Scioto Co. Clyde H. Jones.

1889. *Aralia nudicaulis* L. Wild Sarsaparilla. Hocking Co. B. F. DeHays. Clark Twp., Coshocton Co. F. B. Selby.

1891. *Panax trifolium* L. Dwarf Ginseng. Clark Twp., Coshocton Co. F. B. Selby.

1897. *Sanicula canadensis* L. Short-styled Snakeroot. Ridge Twp., Van Wert Co. M. B. Overholt.

1898. *Sanicula trifoliata* Bickn. Large-fruited Snakeroot. Paris Twp., Stark Co. Don M. Brown.

1899. *Daucus carota* L. Wild Carrot. Knox Co. L. E. Yarman.

1902. *Deringa canadensis* (L.) Ktz. Honewort. Ridge Twp., Van Wert Co. M. B. Overholt.

1904. *Washingtonia claytoni* (Mx.) Britt. Woolly Sweet-cicely. Cars Run, Pike Co. Gordon S. Crowl. Berne Twp., Fairfield Co. William Goslin.

1905. *Washingtonia longistylis* (Torr.) Britt. Long-styled Sweet-cicely. Canton Twp., Stark Co. Don M. Brown.

1907. *Thaspium trifoliatum* (L.) Britt. Purple Meadow-parsnip. Berne Twp., Fairfield Co. William Goslin.

1908. *Thaspium barbinode* (Mx.) Nutt. Hairy-jointed Meadow-parsnip. Berne Twp., Fairfield Co. Robert Goslin.

1909. *Thaspium pinnatifidum* (Buckl.) Gray. Cut-leaf Meadow-parsnip.

1912. *Pastinaca sativa* L. Garden Parsnip. Ridge Twp., Van Wert Co. M. B. Overholt. Berne Twp., Fairfield Co. William Goslin.

1914. *Heracleum lanatum* Mx. Cow-parsnip. Berne Twp., Fairfield Co. William Goslin.

1919. *Zizia aurea* (L.) Koch. Early Meadow-parsnip. Berne Twp., Fairfield Co. William Goslin.

1920. *Zizia cordata* (Walt.) DC. Heartleaf Meadow-parsnip. Bass Island, Ottawa Co. Edward S. Thomas. Madison Twp., Fairfield Co. Gene Rea.

1921. *Taenidia integerrima* (L.) Drude. Yellow Pimpernel. Canton Twp., Stark Co. Don M. Brown.

1926. *Sium cicutaefolium* Schrank. Water-parsnip. Warren Co. Floyd Bartley and Leslie L. Pontius.

1929. *Cicuta maculata* L. Spotted Water-hemlock. Hocking Co. William Goslin.

1940. *Cornus stolonifera* Mx. Red-osier Dogwood. Berne Twp., Fairfield Co. William, Robert and Charles Goslin.

1941. *Cynoxylon floridum* (L.) Raf. Flowering Dogwood. Athens, Athens Co. Warren Abbott.

1944. *Houstonia caerulea* L. Bluets. Washington Twp., Holmes Co. John H. Schaffner.

1951. *Cephalanthus occidentalis* L. Buttonbush. Ridge Twp., Van Wert Co. M. B. Overholt.

1954. *Diodia teres* Walt. Rough Buttonweed. Ross-Hocking Park, Ross Co. William Goslin.

1958. *Galium circaezans* Mx. Wild Licorice. Madison Twp., Fairfield Co. Edward S. Thomas and Charles E. Walker.

1960. *Galium aparine* L. Common Cleavers. Ridge Twp., Van Wert Co. M. B. Overholt. Pleasant Twp., Fairfield Co. William Goslin.

1965. *Galium concinnum* T. & G. Shining Bedstraw. Pleasant Twp., Fairfield Co. William Goslin.

1966. *Galium claytoni* Mx. Clayton's Bedstraw. Berne Twp., Fairfield Co. William Goslin.

1969. *Sambucus canadensis* L. Common Elderberry. Lancaster, Fairfield Co. William Goslin.

1970. *Sambucus racemosa* L. Red Elderberry. Paris Twp., Stark Co. Don M. Brown.

1972. *Viburnum acerifolium* L. Maple-leaf Arrow-wood. Jackson Twp., Perry Co. William Goslin.

1980. *Viburnum cassinoides* L. Withe-rod. Ridge Twp., Van Wert Co. M. B. Overholt.

1982. *Viburnum prunifolium* L. Black Haw. Union Co. B. F. DeHays. Greenfield Twp., Fairfield Co. William Goslin. Greene Twp., Adams Co. Edward S. Thomas.

1985. *Triosteum aurantiacum* Bickn. Scarlet-fruited Horse-gentian. Knox Co. L. E. Yarman.

1988. *Symphoricarpos symphoricarpos* (L.) Macm. Coralberry. Flint Ravine, Franklin Co. William Goslin.

1989. *Lonicera tatarica* L. Tartarian Honeysuckle. Escaped from cultivation in Louisville, Stark Co. Ted Grisez.

1993. *Lonicera japonica* Thunb. Japanese Honeysuckle. Berne Twp., Fairfield Co. William Goslin.

1994. *Lonicera sempervirens* L. Trumpet Honeysuckle. Greenfield Twp., Fairfield Co. Robert Goslin.

1997. *Lonicera glaucescens* Rydb. Glaucescent Honeysuckle. South Bass Island, Ottawa Co. Edward S. Thomas. Cliff Creek, Ross Co. Gordon S. Crowl.

2004. *Valerianella radiata* (L.) Dufr. Beaked Corn-salad. Berne Twp., Fairfield Co. William Goslin.

2014. *Specularia perfoliata* (L.) A. DC. Venus'-looking-glass. Falls Twp., Hocking Co. Ralph Walker.

2015. *Lobelia cardinalis* L. Cardinal Lobelia. Clark Twp., Coshocton Co. F. B. Selby. Adams Co. Clyde H. Jones.

2016. *Lobelia syphilitica* L. Blue Lobelia. Falls Twp., Hocking Co. Ralph Walker. Knox Co. L. E. Yarman. Adams Co. and Marion Prairie, Marion Co. Clyde H. Jones.

2017. *Lobelia puberula* Mx. Downy Lobelia. Scratch Hollow, Pike Co. Gordon S. Crowl.

2022. *Dipsacus sylvestris* Huds. Wild Teasel. Ridge Twp., Van Wert Co. M. B. Overholt. Knox Co. L. E. Yarman.

2027. *Ambrosia trifida* L. Giant Ragweed. Pleasant Twp., Clark Co. and Marion Prairie, Marion Co. Clyde H. Jones.

2029. *Ambrosia elatior* L. Roman Ragweed. Knox Co. L. E. Yarman.

2030. *Heliopsis helianthoides* (L.) Sw. Smooth Oxeye. Putnam Co. M. B. Overholt.

2031.2. *Golinsoga ciliata* (Raf.) Blake. Galinsoga. Lancaster, Fairfield Co. William Goslin. Knox Co. L. E. Yarman.

2033. *Rudbeckia hirta* L. Black-eyed-Susan. Marion Prairie, Marion Co. Clyde H. Jones.

2036. *Rudbeckia sullivanti* Boynt. & Bead. Sullivant's Cone-flower. Harmony Twp., Clark Co. Edward S. Thomas.

2037. *Rudbeckia umbrosa* Boynt. & Bead. Woodland Cone-flower. Alfred Lonsing.

2039. *Rudbeckia laciniata* L. Tall Cone-flower. Putnam Co. M. B. Overholt. Ross and Pike Co. Gordon S. Crowl. Berne Twp., Fairfield Co. William Goslin.

2039a. *Rudbeckia laciniata* var. *hortensia* Bail. Golden-glow. Vienna, Clinton Co. Katie M. Roads.

2040. *Echinacea purpurea* (L.) Moench. Purple Cone-flower. Scioto Co. Clyde H. Jones.

2043. *Helianthus microcephalus* T. & G. Small Wood Sunflower. Berne Twp., Fairfield Co. William Goslin.

2045. *Helianthus giganteus* L. Giant Sunflower. Madison Twp., Scioto Co. Conrad Roth.

2052. *Helianthus divaricatus* L. Woodland Sunflower. Berne Twp., Fairfield Co. William Goslin.

2064. *Helianthus annuus* L. Common Sunflower. Hocking Twp., Fairfield Co. Robert Goslin.

2068. *Ridan alternifolius* (L.) Britt. Ridan. Clear Creek, Hocking Co. Edward S. Thomas. Berne Twp., Fairfield Co. Robert and William Goslin.

2072. *Bidens laevis* (L.) B. S. P. Smooth Bur-marigold. Pleasant Twp., Fairfield Co. William Goslin.

2075. *Bidens coronata* (L.) Britt. Tall Tickseed. Madison Twp., Scioto Co. Conrad Roth. Greenfield Twp., Fairfield Co. Robert Goslin.

2080. *Bidens bipinnata* L. Spanish-needles. La Fayette Twp., Coshocton Co. F. B. Selby. Nile Twp., Scioto Co. Conrad Roth. Lancaster, Fairfield Co. Robert Goslin.
2083. *Coreopsis tripteris* L. Tall Tickseed. Whiskey Run, Pike Co. Gordon S. Crowl.
2088. *Polymnia canadensis* L. Small-flowered Leaf-cup. Lebanon, Warren Co. Eugene Good and Charles Dambach.
2095. *Silphium terebinthinaceum* Jacq. Prairie-dock. Warren Co. Floyd Bartley and Leslie L. Pontius.
2096. *Helenium autumnale* L. Common Sneezeweed. Berne Twp., Fairfield Co. William and Robert Goslin.
2106. *Gnaphalium obtusifolium* L. Fragrant Cudweed. Knox Co. L. E. Yarman.
2109. *Gnaphalium purpureum* L. Purplish Cudweed. Paris Twp., Stark Co. Don M. Brown.
2110. *Anaphalis margaritacea* (L.) Benth. & Hook. Pearly Everlasting. Mantua Portage Co. Don M. Brown.
2114. *Antennaria neodioica* Greene. Smaller Everlasting. Madison Twp., Scioto Co. Floyd B. Chapman and Conrad Roth.
2115. *Antennaria neglecta* Greene. Field Everlasting. Berne Twp., Fairfield Co. Robert Goslin.
2118. *Chrysopsis mariana* (L.) Ell. Maryland Golden-aster. Huntington Twp., Gallia Co. Clyde H. Jones.
2120. *Solidago bicolor* L. White Goldenrod. Adams Co. Clyde H. Jones.
2121. *Solidago hispida* Muhl. Hairy Goldenrod. Berne Twp., Fairfield Co. Robert Goslin.
2122. *Solidago flexicaulis* L. Zig-zag Goldenrod. Adams Co. Clyde H. Jones.
2123. *Solidago caesia* L. Wreath Goldenrod. Eden Twp., Licking Co. Warren Abbott.
2127. *Solidago speciosa* Nutt. Showy Goldenrod. Nile Twp., Scioto Co. Floyd B. Chapman.
2130. *Solidago canadensis* L. Canada Goldenrod. Eden Twp., Licking Co. Warren Abbott.
2132. *Solidago rugosa* Mill. Wrinkled-leaf Goldenrod. Scioto Co. Clyde H. Jones.
2133. *Solidago patula* Muhl. Roughleaf Goldenrod. Eden Twp., Licking Co. Warren Abbott.
2134. *Solidago ulmifolia* Muhl. Elmleaf Goldenrod. Eden Twp., Licking Co. Warren Abbott.
2152. *Aster cordifolius* L. Common Blue Wood Aster. Greenfield Twp., Fairfield Co. Robert Goslin.
2153. *Aster lowrieanus* Port. Lowrie's Aster. Licking Co. A. E. Waller.
2160. *Aster novae-angliae* L. New England Aster. Old Man's Cave, Hocking Co. W. G. Stover.
2162. *Aster phlogifolius* Muhl. Thinleaf Purple Aster. Adams Co. Clyde H. Jones.
2169. *Aster vimineus* Lam. Small White Aster. Madison Twp., Scioto Co. Floyd B. Chapman and Conrad Roth.
2176.1. *Aster pilosus* Willd. Jackson Twp. Stark Co. Don M. Brown.
2179. *Erigeron philadelphicus* L. Philadelphia Fleabane. Berne Twp., Fairfield Co. William Goslin. Athens, Athens Co. and Lawrence Co. Warren Abbott. Ridge Twp., Van Wert Co. M. B. Overholt.
2180. *Erigeron ramosus* (Walt.) B. S. P. Daisy Fleabane. Madison Twp., Scioto Co. Floyd B. Chapman and Conrad Roth.
2181. *Erigeron annuus* (L.) Pers. White-top Fleabane. Berne Twp., Fairfield Co. Robert Goslin.
2182. *Leptilon canadense* (L.) Britt. Common Horseweed. Greenfield Twp., Fairfield Co. William Goslin.
2187. *Eupatorium maculatum* L. Spotted Joe-Pye-weed. Berne Twp., Fairfield Co. William and Robert Goslin. Mantua Portage Co. Don M. Brown.
2188. *Eupatorium purpureum* L. Purple Joe-Pye-weed. Berne Twp., Fairfield Co. William, Charles and Robert Goslin.
2190. *Eupatorium altissimum* L. Tall Thoroughwort. Pleasant Twp., Clark Co. Clyde H. Jones.

2191. *Eupatorium sessilifolium* L. Upland Boneset. Tiverton Twp., Coshocton Co. F. B. Selby.
2194. *Eupatorium urticaefolium* Reich. White Snake-root. Berne Twp., Fairfield Co. William Goslin.
2195. *Eupatorium aromaticum* L. Smaller Snake-root. Hocking Twp., Fairfield Co. William Goslin.
2201. *Lacinaria scariosa* (L.) Hill. Large Blazing-star. Muskingum Co. Floyd VonOhlen.
2202. *Lacinaria spicata* (L.) Ktz. Dense Blazing-star. Liberty Twp., Jackson Co. Floyd Bartley and Leslie L. Pontius.
2204. *Vernonia altissima* Nutt. Tall Ironweed. Knox Co. L. E. Yarman. Berne Twp., Fairfield Co. William Goslin.
2212. *Achillea millefolium* L. Common Milfoil. Hocking Co. B. F. DeHays.
2213. *Chrysanthemum leucanthemum* L. Oxeye Daisy. Knox Co. L. E. Yarman. Berne Twp., Fairfield Co. William Goslin.
2220. *Tanacetum vulgare* L. Common Tansy. Old Man's Cave, Hocking Co. W. G. Stover.
2234. *Senecio plattensis* Nutt. Prairie Squaw-weed. Winesburg, Holmes Co. Don M. Brown. Peach Point, Ottawa Co. Edward S. Thomas.
2237. *Mesadenia atriplicifolia* (L.) Raf. Pale Indian-plantain. Greenfield Twp., Fairfield Co. William and Robert Goslin.
2238. *Mesadenia tuberosa* (Nutt.) Britt. Tuberous Indian-plantain. Warren Co. Floyd Bartley and Leslie L. Pontius.
2239. *Erechtites hieracifolia* (L.) Raf. Fireweed. Keene Twp., Coshocton Co. F. B. Selby.
2246. *Cirsium altissimum* (L.) Spreng. Tall Thistle. La Fayette Twp., Coshocton Co. F. B. Selby. Berne Twp., Fairfield Co. William Goslin. Cutler, Washington Co. W. P. Porter.
2266. *Cynthia virginica* (L.) D. Don. Virginia Cynthia. Vinton Co. William Goslin. Scioto Co. Clyde H. Jones.
2270. *Apargia autumnale* (L.) Hoffm. Fall Hawkbit. Medina Co. Fred H. Norris.
2277. *Hieracium gronovii* L. Gronovius' Hawkweed. Jackson Twp., Perry Co. William Goslin.
2282. *Hieracium pratensis* Tausch. Field Hawkweed. Madison Twp., Fairfield Co. Edward S. Thomas and Charles E. Walker.
2289. *Nabalus asper* (Mx.) T. & G. Rough Rattlesnake-root. Berne Twp., Fairfield Co. William and Robert Goslin.
2304. *Lactuca canadensis* L. Tall Yellow Lettuce. Hickson Run, Pike Co. Gordon S. Crowl.
2307. *Lactuca saligna* L. Willow Lettuce. Carroll, Fairfield Co. William Goslin.
2308. *Lactuca virosa* L. Prickly Lettuce. Union Co. B. F. DeHays. Lancaster, Fairfield Co. William Goslin. Knox Co. L. E. Yarman.
2309. *Leontodon taraxacum* L. Dandelion. Lancaster, Fairfield Co. William Goslin.

BOOK NOTICES

More Biological Symposia

This second volume puts into print addresses on Speciation, Defense Mechanisms in Plants and Animals, The Biological Basis of Social Problems, and Regeneration. In the section on speciation, Hebbs reports that the results of experimental hybridization in fish conform to Galtonian rather than to Mendelian genetics. He believes that the environment has an effect in producing characteristics associated with different living conditions. For example, concerning blind cave fish he says, "Something that is inherent in life in absolute darkness not only permits but forces the degeneration of the eyes and of pigment." In contrast, Dice states from his work on Peromyscus the more generally accepted view that "the variability of species and subspecies, at least in mammals, is not primarily due to direct influence of the environment upon the individual animals, but is based upon variations in heredity." As there is good evidence that some subspecies of

Peromyscus had a polyphyletic origin it is suggested that a subspecies should be considered an ecologic trend in place of the current concept of a subspecies as a unit of descent. Among other chapters in this section is a mathematical treatment by Sewell Wright.

The three chapters on defense mechanisms deal with local responses to parasites, immunity to viruses, and reactions to injected foreign substances.

Regeneration in the annelids occurs in different ways in different genera. In some genera where neoblasts are plentiful head regeneration does not occur while in others head regeneration does occur without involving neoblasts. It seems that regeneration is not accomplished from undifferentiated embryonic cells but from dedifferentiated tissue cells.

The lectures on the biological basis of social problems contain much that is controversial. The opening chapter is a denial of religion. In another chapter the "ethics of enmity" is described as a useful instrument in evolution in a world where there are so many creatures whose interests are essentially antagonistic. When applied to human behavior serious objection may be made to the comparison presented of defensive warfare to defense from a pack of wolves. The chapter on A Biologist's Appreciation of Religion as a Factor in Social Evolution closes with two suggestions for the "secularization of morals." Of one the author says it "might work, but I am afraid that it will not," and of the other that it is "contrary to the American idea of personal freedom." This is the dilemma of a people who "break away from the teachings of religion and permit their morality to become as lax as ours has become."—*B. Davidheiser.*

Biological Symposia, volume II, edited by Jaques Cattell. Lancaster, Penn., The Jaques Cattell Press. 1941. $2.50.

Birding Along the Maine Coast

This fascinating book by the wife of one of the country's leading ornithologists is an account of first-hand experiences with the oceanic birds that breed on the rocky islands off the Maine coast. It not only contains a great deal of information about the life history and habits of these birds, but is full of vivid anecdotes on the trials and tribulations of a field ornithologist. The reader will not get far in the book before he will begin to share the author's enthusiasm, and will almost see, hear, and smell the scenes described.

The book tells of the author's early interests and experiences in bird study, and of her trips with her husband to various islands off the Maine coast to study and photograph puffins, petrels, cormorants, gulls, terns, great blue herons, ospreys, and other birds. Most of these studies were made in the vicinity of Muscongus Bay, Maine, and near the mouth of the Bay of Fundy. The Cruickshanks have spent the past five summers at the Audubon Nature Camp, located in Muscongus Bay, where Mr. Cruickshank is instructor in bird study and Mrs. Cruickshank is camp photographer.

Throughout the book the reader can feel the author's deep interest in birds and conservation. She describes some of the work that is being done for the protection of the birds along the Maine coast, and the results that have been obtained. Though not obviously so, the book is an eloquent appeal for the conservation of these oceanic birds.

That the attempts of the Cruickshanks to secure good bird pictures were successful is attested by the fifty photographs which illustrate the book. These photographs, by Allan D. Cruickshank, are among the finest of hundreds he has taken. They are for the most part excellently reproduced, though the gannet picture opposite page 114 seems a rather poor reproduction of a very striking photograph. The illustrations would probably be more effective if they were better distributed through the book. The only picture of the author appears between pp. 50 and 51, where she is shown holding a gull about to be banded.

This is a book which everyone interested in birds or the out-of-doors will greatly enjoy.—*D. J. Borror.*

Bird Islands Down East, by Helen Gere Cruickshank. xii plus 123 pp. New York, The Macmillan Company. 1941. $2.50.

THE OHIO JOURNAL OF SCIENCE

VOL. XLI SEPTEMBER, 1941 No. 5

THE HEART AND THE RED BLOOD CELLS AS GENERATOR AND DISTRIBUTORS OF STATIC ELECTRICITY

PART I by GEORGE CRILE, M. D.,
PART II by OTTO GLASSER, Ph. D., and DANIEL P. QUIRING, Ph. D.,
Research Division, Cleveland Clinic Foundation

I. A THEORETICAL CONCEPTION

Physiologists are agreed that electric stimulation is the equivalent of physiological stimulation.

Any substance moving through air or through water takes on static charge, and the charge is related to the speed of the movement.

The red blood cells are ideally evolved as receptors and carriers of static charge. This is seen in the extreme thinness of their covering films ($^{1}/_{2,500,000}$ cm. thick), in their biconcavity, which provides a larger surface per mass, and in their irregular shape, which increases tumbling and friction and thereby produces higher charge.

The irregular cavities of the heart and the heart's contractions form an ideal mechanism for friction and movement, required for accumulating static electricity. The highest electric charge would be expected in the left ventricle, the lowest in the vena cava, since electric charge is highest with the maximum speed of movement. As the red blood cells slow down in passing from the left ventricle to the capillaries, the electric charge is distributed to the walls of the blood vessels and to the tissues beyond. The greatest distribution would therefore occur in the capillaries, where the movement of the red blood cells is extremely slow.

The heart as a generator and the red blood cells as distributors collaborate to stimulate electrically every tissue and organ of the body. As each contraction of the heart contributes electrical stimulation to the entire arterial tree, it establishes peripheral resistance in the arterial system, required for the proper circulation of the blood. Thus the heart and the red blood cells contribute to the tone and the physiological activity of the entire organism.

The heart responds instantly to various simulations of the environment, such as danger. This response occurs through the special senses, the stimulus passing from the brain over the sympathetic nerves down to the junction between the celiac ganglion and the aortic wall. This junction would seem to be the point of communication between the external and the internal environment of the animal, analogous to the countless nerve end plates between the voluntary nerve fibers and voluntary muscle fibers, which are synaptic junctions between the internal and external environment.

With each pulse of the heart a wave of electrical stimulation is distributed to the vascular walls of the entire arterial tree. Thus the heart contraction sets up its own peripheral resistance, and this resistance sets up stimulating mechanical pressure in turn on the walls of the heart. This would appear to be an important factor in circulation of the blood.

It would appear that the celiac ganglion is the mediator between the sense stimuli of the environment and the electrifier of the organism, the heart and the red blood cells, with their power of generating and distributing static electricity. These conceptions have been tested in the Biophysics Laboratory of the Cleveland Clinic Foundation by Dr. Otto Glasser and Dr. D. P. Quiring

II. POTENTIAL GRADIENTS OF THE BLOOD AND ORGANS OF CERTAIN MAMMALS

Living organisms have electrical properties. One of these properties is the potential gradient which exists between different organs. This potential gradient lends itself to accurate measurement, and it is characteristic for the organism under investigation and also for the condition it is in at the time of the experiment.

For the determination of potential gradients in living organisms, we have built a microvoltmeter on the general principles suggested by Burr and Lane.[1] This instrument is sensitive and stable and draws a minimum amount of current from the tissue. It consists of a balanced bridge circuit which permits detecting voltage gradients as small as a few microvolts. Contact between the instrument and tissue is made by two reversible, nonpolarizable silver-silver chloride electrodes. These are immersed in a balanced physiological saline solution and are connected through glass and rubber tubing to two glass pipets which are in turn inserted into the tissue. These glass pipets may be variously shaped, depending upon the organs into which they are to be inserted. Readings are taken on a sensitive bridge galvanometer which is directly calibrated in microvolts. For single readings, a Rubicon galvanometer with a sensitivity of about 0.0032 micro-amperes per division, and for continuous records, a General Electric photoelectric recording galvanometer with a sensitivity of about 0.02 micro-amperes per division, were used. Figure 1 shows a schematic diagram of the apparatus.

---

[1] Burr, H. S., C. T. Lane, and L. F. Nims: A Vacuum Tube Microvoltmeter for the Measurement of Bioelectric Phenomena. Yale J. Biol. & Med. 9: 65–76, 1936.

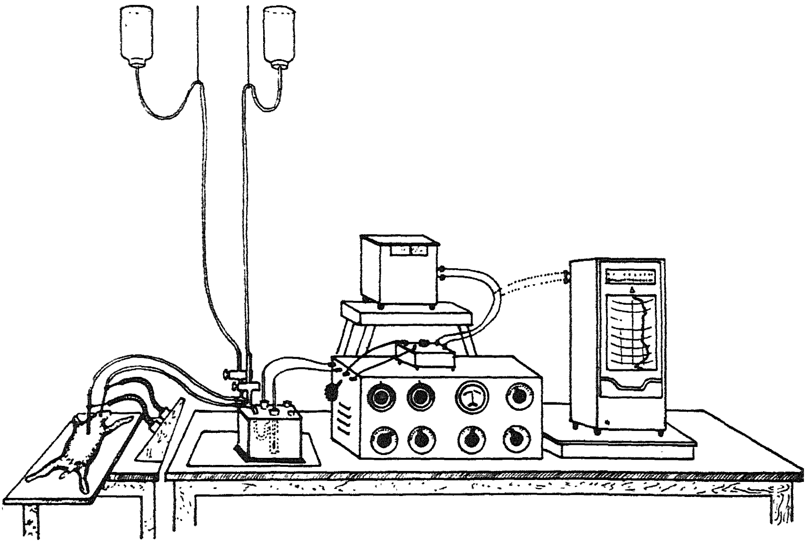


Fig. 1. Microvoltmeter to measure potential gradients in animals.

With this microvoltmeter, potential differences were measured between various points in a series of 265 animals, 245 of which were rabbits. In practically all the animals we used the retina of the eye as the location for one of the pipet-electrodes, after it was determined that for these measurements the eye acts as part of the brain. The location of the other pipet-electrode was generally the lumen of the left ventricle of the heart, and in selected cases also the kidney, liver, adrenal gland, bladder, genital organs, rectum, ileocolic junction, stomach, duodenum and spleen. The electrodes were inserted while the animal was under ether anesthesia.

Some significant general observations were made. With blood circulating through it, the polarity of the left ventricle was always negative compared to that of the brain. The polarity of all other organs of the normal animal was also negative compared to that of the brain, with the exception of the stomach.

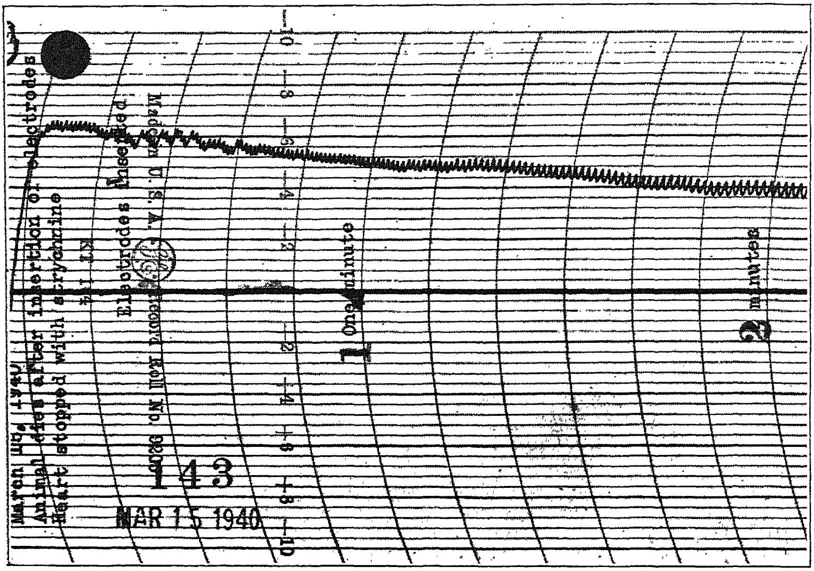


Fig. 2. Death curve in normal rabbit. Interval of time, 10 seconds.

The potential gradient between eye and left ventricle in almost 200 rabbits was determined to be 2.28 ± 0.038 millivolts.

The potential gradient between eye and right auricle in 10 animals measured 1.18 ± 0.073 millivolts.

If the animal continues to live after the electrodes have been inserted, the potential gradient is essentially maintained during life. If death occurs, the gradient decreases more or less rapidly. Our experiments have taught us again that it is difficult to determine the exact time of tissue death. Generally, cessation of breathing is referred to as death. However, that does not mean that the other organs of the animal stop functioning at the same time. Many of our records show that after breathing stops, the heart continues to beat for a long time. If the heart slows down, the beats superimposed upon our potential gradient curves continue in many cases even after the main potential difference between heart and eye has disappeared. All other organs also show definite potential gradients long after death, although all of them decrease more or less rapidly after breathing stops. The organs which lose their potentials quickest are the liver and the brain. Then follow the adrenal glands and the organs of the genito-urinary and gastrointestinal tracts.

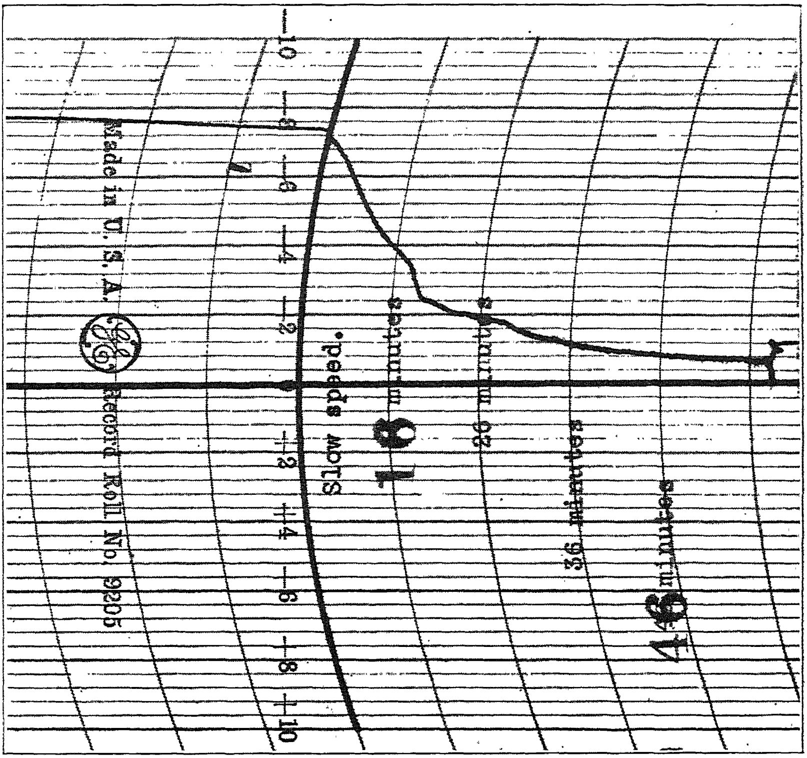


Fig. 3. Death curve in normal rabbit after injection of 2 cc. of chloroform into heart. Interval of time, 10 minutes.

The kidney potentials seem to be the most stable, and the kidney therewith the longest lived organ of those investigated. According to our observations, we would say that death of all organs has taken place when no potential differences between them and any other part of the body can be determined. This point is not reached until several hours after the animal has stopped breathing. A large series of our records illustrates this fact.

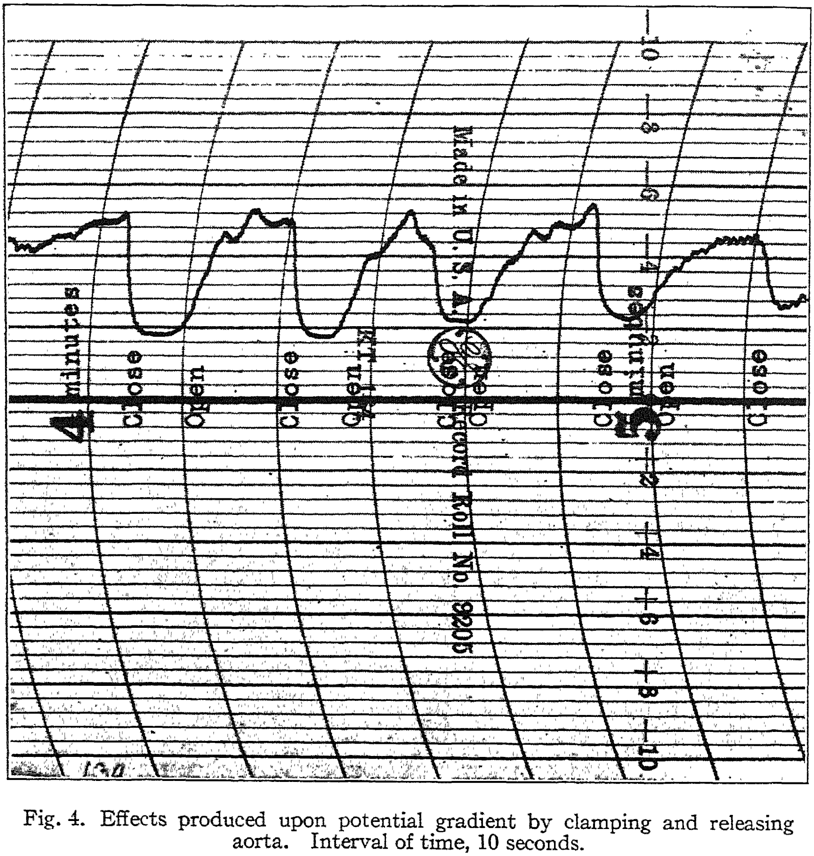


Fig. 4. Effects produced upon potential gradient by clamping and releasing aorta. Interval of time, 10 seconds.

Figure 2 illustrates the drop in the potential gradient after the animal has stopped breathing. In this case the rabbit stopped breathing shortly after the electrodes were inserted in the left ventricle and eye. During the next 7 minutes a definite decrease in the potential difference was noted and, superimposed upon the potential gradient curve, the number and amplitudes of the heart beats were observed. During the seventh minute, 2 cc. of strychnine, 1:10, was injected directly into the heart, which then stopped beating after one minute.

Figure 3 illustrates a death curve following injection of 2 cc. of chloroform into the heart.

A definite change in potential gradients can be produced by stopping the flow of blood for short intervals. This was done by manipulation of a clamp which was fastened around the aorta at its emergence from the heart and which permitted us to stop or start the flow of blood to the heart at will. Figure 4 illustrates the results obtained in one such experiment. Electrodes were inserted into the eye and the left ventricle of a rabbit. In the third minute the blood flow was stopped by closing the clamp, and a definite decrease in the potential difference of over 50 per cent was observed. Upon opening the clamp, the potential returned to the original value. This procedure was repeated eight times during the next two minutes, always with the same result. From the eleventh to the fifteenth minute the same

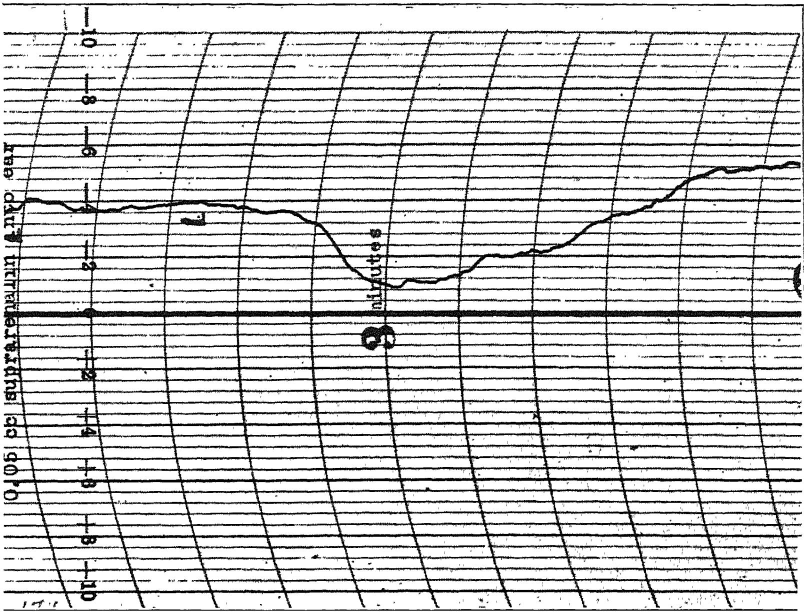


Fig. 5. Effects of adrenalin injected into adrenalectomized rabbit upon potential gradient. Interval of time, 10 seconds.

experiment was repeated about ten times with the same results. The time of stopping the blood flow in each single experiment was approximately 5 seconds. The superimposed heart beats permit the conclusion that the number of beats per minute did not change during the clamping of the aorta.

Figure 5 shows the effect of 0.05 cc. suprarenalin injected into the ear at two minute intervals upon an adrenalectomized rabbit. An initial decrease of the potential gradient about a minute after injection was observed in all cases. This was followed by a rapid increase which carried the potential well beyond the initial value. Repeated doses after the first few injections yielded but a small effect upon the potential gradient.

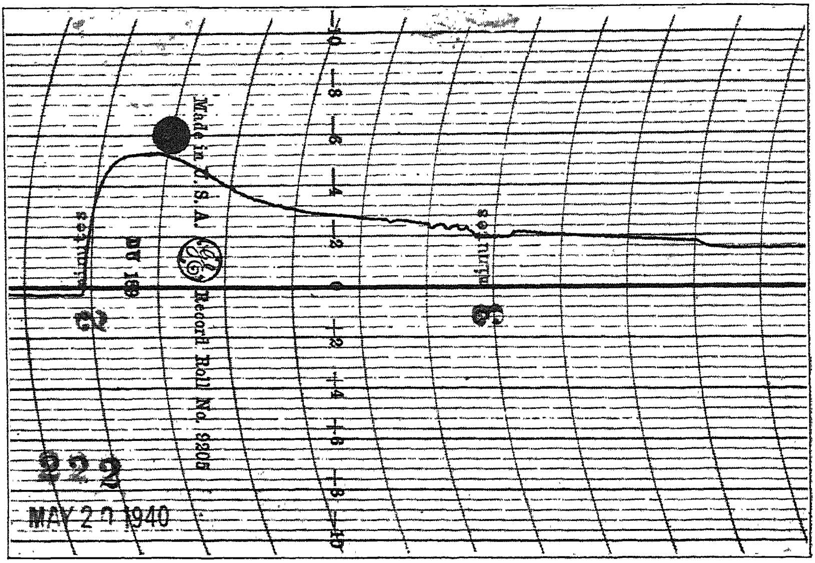


Fig. 6. Effect of pithing upon potential gradient. Rapid drop of potential difference. Interval of time, 10 seconds.

Adrenalectomized rabbits were chosen for these experiments rather than the normal because only a slight increase in potential occurred in the normal animal. Presumably this is due to the fact that the normal secretion from the adrenal glands in an unoperated animal is sufficiently high to obscure the effects of added adrenalin doses from without upon the potential gradient. It is only after the adrenal glands of a normal rabbit have been removed that this effect can be observed. Electrical stimulation directly to the adrenal glands of a normal rabbit does, however, produce a marked increase in the potential gradient. It becomes apparent that there are still a number of unknown factors with reference to the adrenalin secretion in the body as well as with reference to the effects of adrenalin introduced from without. It appears that the normally functioning body maintains a definite adrenalin balance which is difficult to disturb. However, if the balance is upset by injury or experimental interference, marked variations in the potential gradients can be observed even after addition of small amounts of adrenalin.

Narcotic agents like cocaine and morphine in small doses produce relatively small effects upon the potential gradients.

If, however, larger doses of the order of $\frac{1}{2}$ mg. of cocaine were introduced into the ear, rapid fall in potential ending in convulsions and death was observed. Caffeine injected into the ear in small doses (10 mg. in 1 cc. of water) produced considerable increase in the potential gradient and subsequently showed effects in maintaining the potential level similar to that observed with cocaine.

In order to determine whether or not potential gradients could be maintained in the absence of direct nervous connection between the brain and the heart, a number of experiments were carried on in which the animal was pithed and in which the vagus and sympathetic nerves leading to the heart were severed. Figure 6 shows the result of one of these experiments upon the potential gradient measured between the eye and the left ventricle. The animal was pithed and the nerve connections severed after the normal gradient was established, and within one minute the potential difference was decreased to one half. Then it established and maintained itself at this level for at least 10 minutes.

In addition to the experiments involving potential gradients between the heart and the brain as represented by the retina of the eye, a large series of observations, as already indicated, upon the gradients of other organs with reference to the brain was made. The results have not been included in the above discussion. It is sufficient to state, however, that the liver, kidney, adrenal glands, bladder, muscle, rectum, colon, ileocolic junction, stomach, duodenum and spleen all showed a negative polarity in reference to the brain with the exception of the stomach.

Our experiments show that the polarity of the blood in the left ventricle of the heart is negative as compared with that of the brain, and furthermore that changes in the agitation of the blood within the heart are accompanied by corresponding changes in the potential gradient. A number of excitatory as well as narcotizing agents were employed to produce such changes. Other methods of interference with the flow of blood, such as momentary stoppage by mechanical means, were followed by a considerable fall in the electrical potential gradient.

It may be concluded from our experiments that the heart beat plays a definite role in the production and maintenance of the potential difference between heart and brain. Specific changes in these potential gradients may be produced by various mechanical, electrical and chemical means at will.

Research and Statistical Methods

This *Yearbook*, like its predecessor, *Research and Statistical Methodology Books and Reviews* of 1933–1938, will be found especially useful both by the teacher of statistical methods and by the investigator who desires expert advice upon the wise choice of books which best suit his purposes, and who also wants suggestions for expanding his own acquaintance with newer research methods as they appear. Among the 359 book titles listed, every major field of scientific investigation is represented, usually by several books. During the period covered by this yearbook—two-thirds of the books were published in 1938–1941—Business and Economics are represented by 73 titles, Education and Psychology by 44, Biology by 28, and Mathematical Statistics by 18. Slightly less than half of these are textbooks suitable for class-room use. The other titles are concerned with fundamental problems of methodology common to all fields, or with expositions of methods for particular subfields. In all, 1,652 reviews of English language books on methodology gathered from 283 journals have been expertly excerpted for evaluative criticisms and arranged for easy reference. Indices of titles, names, and subjects, and of periodicals and publishers are appended.

The editor indicates in the preface that the service may be expanded, provided this edition proves sufficiently useful, by including titles and reviews of foreign language books, and by abstracts and critical reviews of periodical literature on research methods. It is to be hoped that succeeding *Yearbooks* may be assembled annually as long as the publishing activity in the field of research and statistical methodology continues at a high rate.—*E. L. Green.*

The Second Yearbook of Research and Statistical Methodology Books and Reviews. Edited by Oscar Krisen Buros. xx+383 pp. Highland Park, N. J.: The Gryphon Press, 1941. $5.00.

INEXPENSIVE EQUIPMENT FOR THE PREPARATION AND CONCENTRATION OF PURE D_2O OR OF DEUTERIUM-RICH WATER. DESCRIPTION OF CONSTRUCTION AND OPERATION OF THE FORMER OHIO STATE UNIVERSITY HEAVY WATER PLANT[1]

HERRICK L. JOHNSTON and W. HEINLEN HALL[2]
The Ohio State University

During the spring and summer of 1934 we operated, at the Ohio State University, a "heavy water" plant with a capacity for reducing about 100 gallons of water per week. In a period of sixteen weeks about 800 grams of D_2O were produced, in pure or concentrated form, from about 1800 gallons of commercial electrolyte taken from the electrolytic hydrogen cells of the Capital City Products Co. of Columbus.[3]

Although this was one of the largest, and most economical, of the early plants for producing D_2O we have never, heretofore, described it in any detail.[4] A number of features, and observations, warrant some description, for the benefit that they may be to those who have occasion to prepare or concentrate heavy water for research, demonstration or advanced student laboratory use.

While our plant was similar, in the main, to others that have been described (1) it possessed especial simplicity and economy in construction.

General Plan of Operation

The plant was designed to operate in three main stages. The first stage reduced the initial electrolyte to about 1/32 of its initial volume and, in so doing, built up the atomic concentration of deuterium in the hydrogen of the electrolyte from its initial value of about 0.05 of 1% (2) which is about three times the deuterium concentration in normal water (3) to a value of about 0.6 of 1%. This stage was divided into five steps, in each of which the electrolyte was reduced to about half volume.

---

[1] Contribution from the Chemical Laboratory of The Ohio State University.

[2] Now located at Bowling Green State University.

[3] The water from this electrolyte was furnished to us, free of charge, by The Capital City Products Co. About 1400 gallons of distilled water was obtained from the 1600 gallons of electrolyte by distillation from an iron boiler and was made 0.5 N in NaOH for introduction into the first stage of our electrolytic heavy water plant. The residual concentrate from the boiler was diluted with fresh distilled water and returned to the cells of The Capital City Products Co. The distillations were carried out by students in the Chemical Engineering Department under the direction of Professor J. H. Withrow, Chairman of the Department, and Dr. J. A. Koffolt, in active charge of the distillation.

[4] Photographs of sections of the plant, and a brief description, were published in the Ohio Journal of Science **35**, 362 (1935).

About 1000 water-coolled cells of an inexpensive type (types (a) and (b) of Figure 2) were used in this stage.

Between the first and second stages the concentration of alkali in the electrolyte was reduced, by neutralizing the bulk of the solution with CO_2. To accomplish this about 5% of the concentrated solution was set aside, to form the necessary concentration of NaOH for the next stage, and the remainder was neutralized by adding to it pieces of dry ice, in an open five gallon oil can from which the top had been cut away. The water was then distilled away from the bicarbonate solution, in a copper steam can, and added to the 5% of concentrate to form dilute electrolyte ready for the next stage.

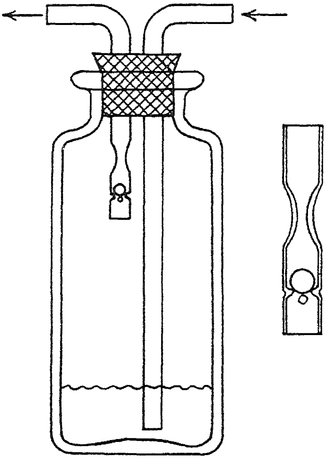


FIGURE 1

The use of solid, rather than gaseous, carbon dioxide appears to have been new with us and possesses the advantages of: (1) economy, (2) rapidity and convenience and (3) partial compensation for the heat evolved in the neutralization reaction by the heat absorbed in the sublimation. It should be noted that the CO_2 neutralization accomplishes normalization (or near normalization) of the oxygen isotope ratio (2), which is changed in the process of electrolysis (3). It may be that the effect of CO_2 from dry ice differs slightly in this respect from that customarily found for CO_2 from tanks, but this depends on the source of the original CO_2 and its method processing.

For the second stage eight tall, water jacketed cells (type f in Figure 2) were employed, in which the electrolyte could be safely reduced to about 1/5 volume in a single step. This was repeated for a second step, after which neutralization by dry ice was carried out in the manner described above. The deuterium concentration at this point in the process was between 6% and 10%.

The third stage was carried out in varying numbers of small cells (type e of Figure 2. We used a maximum of 24) which were constructed out of eight inch Pyrex test tubes. The number of steps and the volume ratio reductions were determined by the desired purity, and the needs of the moment. In the preparation of pure heavy water at least one reduction in alkali concentration was necessary. This was usually effected by distillation of the strong NaOH solution from a Pyrex distilling flask, without neutralization.

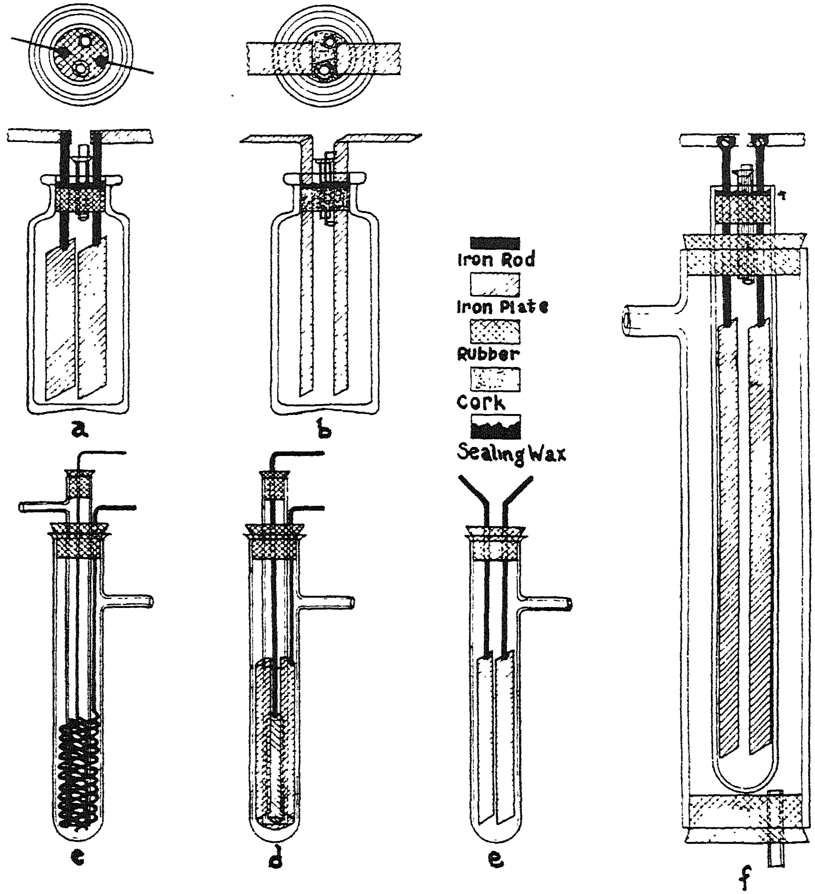


FIGURE 2

Closed cells were used in all steps of operation. In the first four steps this was for the purpose of conducting away the large volume of hydrogen (with oxygen) liberated in the electrolysis.[5] The cells were grouped in banks of 50 each connected through a gas manifold and each of the banks connected to a main steel pipe manifold which terminated in a vertical pipe that projected above the roof of the building. The steel pipe was grounded to carry off static charge produced by the flow of gas. Each of the 50 cell banks was protected against possible explosions in the main manifold or in other banks by a glass bead explosion trap (Figure 1), in series with a spray trap, at the point at which it made connection with the steel pipe manifold. These functioned properly in the few cases in which explosions occurred in 50 cell units, due to eating off of anodes (cf seq).

---

[5] For small laboratory operations closed cells for these early steps can be dispensed with if the cell troughs are placed under a hood or in a location where they receive good ventilation. For this purpose open wide-mouthed bottles connected by U shaped electrodes, and set in troughs of running water may be employed.

In the fourth step of electrolysis (Stage I) the average deuterium concentration of the hydrogen which escaped from the cells was about equal to that in the initial first step electrolyte. In the fifth step the escaping hydrogen had a deuterium enrichment about intermediate between that of the electrolyte at the beginning of steps 1 and 2 respectively. This hydrogen was recovered by recombination of the oxy-hydrogen mixture (cf infra) and returned to the first step. The electrolytic gases from all steps of the second and third stages were likewise recombined and returned to the appropriate position in the plant.

Inexpensive Forms of Closed Electrolytic Cells

Figure 2 illustrates several types of inexpensive closed cells which we built and operated. Any of these may be constructed out of materials usually on hand in a chemical storeroom.

Types (a) and (b) use 500 cc. wide mouthed glass bottles. Type (a) is made by welding short flat electrodes to 3/16″ iron rods which project through two of the four holes drilled[6] in tight fitting rubber stoppers. The other two holes carry: (a), the gas delivery tube which may be of either glass or metal and (b), a glass or metal tube for filling and emptying the cells—(the latter by siphon). The second tube should be of such a size that it can be closed with a small cork. The wetted rubber stopper, with electrodes and tubes in place is forced to a position a little below the top of the bottle neck and covered with ceiling wax. Electrical connections are made either by drilling the projecting ends of the iron rods to take small bolts with which to bolt on narrow connecting strips of sheet copper,[7] or by using battery clips. In the type (b) cells the flat electrodes project through a tight-fitting cork which is cut into three sections by two parallel cuts. The sections of cork were soaked in hot paraffin and the assembled unit covered with sealing wax. U shaped electrodes, used in common by adjacent cells, serve also for connectors. This type of cell is satisfactory for about a month of use but eventually the alkali disintegrates the cork, which then has to be replaced. We originally used (b) type cells on the first stage, but subsequently replaced them all with (a) type cells.

---

[6] It is best to drill these with high speed wood drills lubricated with water. The rubber stopper should be inserted in a hole drilled in a board, during the drilling operation.

[7] In drilling the rods much time is saved if a small flat surface is first ground on one side of the rod, or a thin cut taken with a milling machine, to prevent the drill from slipping. The drill holes should be parallel to the surface of the electrodes so that connectors will not require bending.

Both (a) and (b) cells were set in troughs of running water. They operate best at 5 to 7 amperes, which requires a littel over 4 volts per cell with 0.5 N alkali and results in an approximate 10° temperature head between electrolyte and cooling water. It is not advisable to allow the electrolyte in these cells to drop much below 200 cc. volume as, otherwise, the cells may heat up excessively. We customarily began the first step of electrolysis with 400 cc. of electrolyte and, when this volume was reduced to 200 cc, doubled up the cell contents into one-half of the original cells in preparation for the second step. The same procedure was followed after the second, third and fourth steps.

The construction of type (f) cells is clear from the diagram. The cell compartment is made from Pyrex tubing about 35 mm. in diameter. This cell offers a large cooling surface and operates well at 15 to 20 amperes. The electrolyte can safely be reduced to 1/10 volume in a single step in these cells, if desired.

Type (e) cells were used in the steps of the third and final stage. The thick iron wires that carry the electrodes are forced through small drill holes in the solid rubber stopper. The stopper with the electrodes is removed from the cell when electrolyte is added or removed and wired tightly in place when the cell is in service. This cell is set in an open wide-mouthed bottle through which cooling water circulates. The cell will carry 5 to 6 amperes without difficulty.

The above-mentioned cells permitted the electrolytic oxygen and hydrogen to mix. When, for any reason, we desired to keep them separate, we used cells of type (c) or (d) (a narrow gas outlet for the inner glass tube in (d) similar to that shown in (c) was inadvertently left off the diagram). While (c) is very eaisly constructed the use of cylindrically bent sheet metal, as in (d), is to be preferred because of much lower resistance offered to the current.

Electrodes and Separation Efficiency

Except for four hundred type (b) cells with nickel electrodes, that were subsequently replaced, electrodes for all of the cells were made of No. 20 gauge, unsurfaced Armco iron. This possesses a distinct advantage over nickel and other practical metals for efficient isotope separation. With NaOH electrolyte we obtained, with Armco iron, an electrolytic separation factor[8] of a little more than 8, whose magnitude was practically independent of current density and of the deuterium concentration in the electrolyte. This is the true separation factor applicable to the dry gas. The *practical* separation factor is somewhat less than this (about 6 or 7) due to water vapor carried out with the electrolytic gases.

---

[8] α is most simply defined as the instantaneous ratio of (H/D) in the gas to (H/D) in the water. Thus, if a 10% D_2O solution (H/D = 9) is being electrolyzed and the evolving hydrogen proves to be just 2% in D (H/D = 49) the separation factor is 5.55. For low concentrations of D this resolves into the ratio of % D in the H_2 to % D in the H_2O. Thus, in the above example, 10/2 = 5.0 is nearly the correct value for α.

This factor of 8 compares with one of only 5 for nickel and makes a considerable difference in the efficiency of separation. For example, we found that when we used iron electrodes the deuterium concentration went up by a factor of about 3 for each fourfold reduction in volume. In the sixteen fold volume reduction, during which we allowed the electrolytic gases to escape, the deuterium concentration went up by a factor of 9. With nickel as electrodes the deuterium concentration goes up by a factor of only about 4. Iron electrodes, therefore, more than double the yield of D_2O as against nickel for the plan of operation which we followed.

It is obviously not practical to recombine and reclaim the electrolytic gases from the first and second steps of electrolysis, with iron electrodes, since their deuterium concentration is below that of ordinary water. Recombination in the third step is likewise impractical since the deuterium concentration is only slightly in excess of normal water. Recombination in the fourth step is about the equivalent of a 5% increase in the amount of starting material. The rather considerable amount of gas that would needs be handled to effect this economy makes recovery at this step impractical also. 7/16 of the deuterium present in the starting material is thus lost before, the recovery by recombination and repeated electrolysis becomes practical. Allowance for rejection of gas in the re-electrolysis of the water recovered in stages where recombination is practical brings this theoretical loss to a full 50%. Our 800 gram D_2O production from 1400 gallons of a starting material that held a little more than 2 Kg of D_2O initially is thus a reasonably good yield, and is superior to the yields reported by other plants (1). We experienced small accidental losses in handling. There were evaporation losses during the CO_2 neutralizations, and some electrolyte was lost, early in the operation, by explosions that resulted from corroded-off electrodes.

Recombination of Electrolytic Gases

Recombination of the stoichiometric oxy-hydrogen mixtures was brought about by combustion in a flame formed at the tip of a Pyrex capillary (4). The flame was prevented from firing back through the capillary by the high velocity of gas flow under a small pressure head developed in the cells. The choice of diameter for the capillary was determined by the rate at which the gas was generated—i. e., by the number of cells delivering gas to the burners and by the current.

We obtained best performance with tips made by fusing a four or five millimeter length of Pyrex capillary to a two or three inch length of wider tubing. We have used tips constructed in this manner for three or four weeks of nearly continuous service without need of replacement. With tips of this description, and the proper choice of capillary diameter, we have obtained satisfactory results in the wide range of gas flow that lies between the delivery from a single cell operating on 6 amperes and that of 50 cells operating at 12 amperes. For the latter the flame was over a foot long.

The oxy-hydrogen flames were directed into water-cooled Pyrex tubes that served as condensers. Tubes were chosen of such diameter as to provide at least a quarter-inch clearance around the flame. With very large flames cylinders of copper gauze were inserted in the condensers to protect the glass.

Explosion traps to protect the cells from "backfires" in the combustion train when the gas flow would be reduced were formed from 100 cc. Pyrex round-bottom flasks tubulated at the bottom and filled with fine river sand.[9] These traps proved 100% effective in hundreds of trials with various rates of gas flow.

The burners were allowed to operate over night, without attention, except for stage 3 electrolyses. Because of the value of the water at this stage the electrolyses were given personal attention.

Foaming

Not infrequently, foaming occurred during the first half hour of electrolysis in the first stage and in stages that followed neutralization. The nature of all the impurities responsible for this were not determined but it was found that cork in the electrolyte was a particularly bad foam producer.

The impurities responsible are adsorbed in the surface and carried over with the foam. Addition of a few lumps of calcium chloride to the salvaged spray, followed by distillation, proved effective in correcting this condition. Addition of a small amount of permanganate as well as $CaCl_2$ and distillation nearly to dryness so that chlorine[10] is liberated, is helpful in extreme cases.

Corrosion of Electrodes

During nearly continuous operation of 1000 cells for a period of four months two or three dozen examples of severe corrosion were observed. The comparative infrequency of this trouble made the isolation of its causes, and hence its prevention, the more difficult. The peculiar thing is that an electrode which has been in service many weeks with little or no indication of corrosion may suddenly develop this condition and rust entirely off at the electrolyte surface within a period of six or eight hours. Other cells connected in series with the faulty cell and apparently subjected to the same operating conditions will escape corrosion altogether.

Corrosion is no more frequent with iron than with nickel electrodes. However, the advanced stages of corrosion develop more slowly with nickel on account of the more impervious character of the black oxide coating. For this reason iron offers a somewhat greater hazard in the operation of closed cells through danger of sparks between the electrolyte and an eaten off anode.

Overheated cells are more apt to develop this condition than cells which operate at lower temperatures. Electrolyte removed from a cell in which corrosion has started very frequently (but not invariably) produces this condition in other cells to which it is added. The *distillate* from a contaminated batch of electrolyte is non-corrosive, however. Electrolyte prepared from tap water, or contaminated with tap water, increases the chance of corrosion. The presence of a trace of $CaCl_2$ which reached the distillate during distillation of a foamy batch of electrolyte produced immediate and excessive corrosion in every cell to which this distillate was added. From the latter two observations and the fact that the anode is the electrode which is attacked we conclude that chloride ion, even in traces, is the promoter of corrosion.

---

[9] 60% of this sand passed through a sieve with 50 meshes to the inch. A sample of pure silica whose grains were of approximately 35 mesh size failed to stop explosions, in similar tests.

[10] All traces of chlorine or of chloride ion must be removed from the distillate before return to the cells. Otherwise corrosion results.

The only dependable protection against losses through this hazard lies in frequent inspection. For cells in which the visibility is limited current drop in the circuit containing a faulty cell and excessive heating in the cell itself are reliable criteria. The cell resistance is so increased by corrosion that even in a circuit with twenty-five cells in series corrosion in a single cell results in a 20% to 25% drop in current several hours in advance of actual rusting off.

The Deposit of Alkali Metal

In a few instances we permitted electrolysis to continue until a saturated solution of the alkali hydroxide was formed. This resulted, in one such instance, in an explosion in one of the cells a few minutes after electrolysis was stopped. The cause of the explosion was definitely traced to the presence of free alkali metal which had deposited, under a layer of the solid hydroxide, at the cathode surface. Free alkali metal deposits from aqueous solution, under these conditions, in such quantity that it can be scaled from the electrode and easily identified.

Acknowledgments

We gratefully acknowledge the generosity and helpful co-operation of the Capital City Products Co. of Columbus, who furnished the deuterium-enriched water for this program. We are also grateful to Professor J. H. Withrow and Dr. J. A. Koffolt and their students in Chemical Engineering for their recovery of the potash in the original 1600 gallons of electrolyte. We wish to acknowledge the co-operation of the directors of the Ohio Engineering Experiment Station and of Mr. William McCracken, former university engineer, who made building, generator and electric power facilities available to us. Finally, we wish to thank Dr. C. O. Davis who assisted us in the analysis of the electrolyte and in preliminary experiments with the design and operation of cells.

SUMMARY

The plan of operation of the former "heavy water" plant at The Ohio State University is outlined and several forms of inexpensive closed cells are described.

The advantage of iron electrodes over those of nickel, in plants for the concentration of deuterium, is pointed out and figures given as to the efficiency of deuterium production.

The construction of a durable burner tip for the combustion of the electrolytic gas in the advanced stages of electrolysis is described.

The advantages of solid carbon dioxide as an agent for neutralizing alkaline solutions, in deuterium recovery, are pointed out.

Experience in combatting foam and experiences with corrosion of iron and nickel electrodes and with the deposit of free sodium from concentrated NaOH are described.

LITERATURE CITED

(1) **G. N. Lewis** and **R. T. MacDonald,** J. Chem. Phys. 1,341 (1933); **H. S. Taylor, H. Eyring** and **A. A. Frost,** ibid 1,823 (1933); **F. C. Anderson, Ja. A. Halford** and **J. R. Bates,** ibid 2,342 (1934); **W. G. Brown** and **A. F. Daggett,** ibid 3,216 (1935).
(2) **W. H. Hall** and **H. L. Johnston,** J. Am. Chem. Soc. 57 1515 (1935).
(3) **H. L. Johnston,** J. Am. Chem. Soc. 57,484 (1935).
(4) **H. S. Taylor, H. Eyring** and **A. A. Frost,** J. Chem. Physics 1,823 (1933).

Microscopic Anatomy of the Vertebrates

Dr. Kendall's recent revision of "The Microscopic Anatomy of the Vertebrates," of which he was originally coauthor with Professor Scott, offers a different arrangement and method of presentation which should fit well into beginning courses in histology as they are offered in many Arts College curricula. The author has adhered to the policy of keeping the book small, but it appears that in some instances even the descriptive material is exceedingly abridged. Kendall purposely has avoided the pitfalls of attempting to correlate structure with function. Although that may be dangerous ground on which to tread, it appears that an understanding of modern histology is incomplete without some acquaintance with at least the better established histochemical and histophysiological interpretations commonly accepted by the students of microscopic anatomy.

The book is unique in that the histology and organology of many organs is presented as it appears in each of three or more classes of vertebrates. In this respect the text approaches the requirements of many instructors who offer courses in Comparative Vertebrate Histology. Since this was not the author's objective no word of criticism is voiced but it would be most gratifying to many of us to see a truly comparative histology appear on the booklists. At the present time I believe Kendall's revision is the best approach to a concise treatment in comparative histology even though it was not so designed. The author has made many improvements in the figures, but certain areas are still woefully deficient in the quality of the photographs. The passages on the kidney and endocrines are especially weak in illustrative material. The book would be greatly improved by enlarging all illustrations to bring into relief much detail so important to students of histology.

The reviewer is fully aware of the difficulties confronted by the author in attempting to assemble comparable photographs of good quality to meet the objectives of the text. The literature is vast and scattered and contains a dearth of excellent photographs which would be appropriate for use here. The author is faced with the problem of obtaining tissues from a wide variety of animals, making preparations, and finally solving photomicrographic problems. It is therefore with a feeling of constructive criticism that these suggestions are made.

—*Clinton M. Osborn.*

Microscopic Anatomy of Vertebrates, by James I. Kendall. 342 pp. Philadelphia, Lea and Febiger, 1940.

THE GEOGRAPHY OF THE BELLEVUE AREA

RUTH ROCKWOOD DAUGHERTY

INTRODUCTION

Bellevue, Ohio, is located on the north-south boundary line between the counties of Huron and Sandusky near the middle of the state east and west and twelve miles south of Sandusky Bay.

Bellevue lies on a poorly defined, sand dune covered section of Maumee Beach on the southern border of the Lake Plain. The sink hole topography in the neighborhood has given this town unusual drainage and water problems. The site was chosen for white settlement about one hundred and twenty-five years ago. From the rural simplicity of the pioneer day the present landscapes, including the culture, have unfolded gradually, stimulated by the development of the railroads, and by the limestone industry.

In the following chapters the natural environment is first described, then the pattern and functions of the landscapes before the railroad period, and finally the modern landscape influenced by the railroads.

PHYSICAL CHARACTERISTICS

TOPOGRAPHY

To the north of Bellevue extends the pro-glacial Lake Plain which runs roughly parallel to the southern shore of Lake Erie. This Plain is wider to the west, is broken into strips one and a half to five miles wide by the Whittlesey and Warren beaches, and attains an average total width of about twelve miles. Bellevue is on the southernmost of the three beach ridges, the Maumee, which forms the dividing line between the Lake Plain and the Till Plain. Sand dunes and sink holes have considerably modified the beach topography. The crest of the beach is ill-defined at Bellevue because it has suffered a long period of wind and water erosion. The central part of the town is on the gently northward sloping Lake Maumee plain. The northern edge of the beach, shaped roughly like a horse-shoe, enters the town limits at the northwest corner, swings to the south in a poorly defined line, and leaves the town boundary at the northeast corner. Its crest is broken on the west and south side of the town because of the numerous sand dunes, and on the eastern side intermittent and artificial stream work has etched into the beach. The altitudes of the three beaches are about 780′, 740′, and 680′ above sea-level. They stand from 20′ to 30′ above the bordering Lake Plain and perceptibly above the Till Plain on its border though it rises south.

Their northern slopes, although steeper than their southern slopes, are still gentler than those farther east.

The beaches at this end of the Lake Plain do not stand out as conspicuously above the plain as they do toward Cleveland. They are generally better drained than the Lake Plain because of their elevation and their porous soils.

The Lake Plain—About one-half of the town of Bellevue lies on the Maumee Lake Plain, approximately 745′ high in Bellevue. Sink holes and a few sand dunes modify the topography. This plain rises toward the south approximately 17′ in a mile, steeper toward the Maumee beach and gentler toward the Whittlesey.

The Lake Plain in and west of Bellevue has an undulating surface due to the sand dunes and sink holes. Several areas among these features are poorly drained, even swampy, and spring rains cause water to stand for several days. Because of sinks and sub-surface drainage, streams are few, intermittent, and follow poorly developed valleys. One such valley, about 15′ deep, on the eastern side of the town has been dredged. Most of the drainage is thus dependent upon the sink holes and porosity of the mantle rock, which are not sufficient during heavy rains.

Glacial Plain—The southernmost part of this town, south of Maumee beach, is on the level Till Plain. Feeble and intermittent streams also help to drain this plain. In the southeast corner of this town is a glacial kettle whose rim has been strengthened by man. This pond, called the Old Mill Pond, broke through its banks during the flood of 1936. They were hurriedly rebuilt and the pond left undrained although it now serves no particular use.

The sink holes[1] within this area are both natural and artificial. Eighteen or more natural sink holes occur within the town, each usually in a depression varying from 5′ to 15′ in depth and made by washing earth down the hole. These sometimes fill up with surface wash which has to be sucked or dug out to restore the drainage. About seven more are found in town on the Lake Plain and they continue northward as far as Castalia.

A Geological Section—The beach sands, the gravels of the ridges, and the stratified and thickly bedded lake clays of the Lake Plain form the mantle rock north and a varying layer of drift mantles all south. Glacial drift, which varies in thickness from 18′ to about 80′, underlies the lake sediments.

The Columbus limestone and the Lucas dolomite of the Devonian system form the bedrock for this region. Both are strong rock, and though shattered and disturbed some by solution slumping, are the basis for a valuable industry (6). The quarry is opened to a depth of approximately 45′. Beneath these Devonian rocks other limestones are known but no values have ever been discovered in them near Bellevue.

Caves and underground passages in this limestone are frequent. Some of the small caves in the region bordering the town have been filled in. Drillings for artificial sink holes vary from 32′ to 248′, where they reach crevices in the limestone that carry away water and waste.

---

[1] Hubbard, G. D., shown on a map of sink holes drawn in 1913.

CLIMATE

Bellevue is in the Temperate Zone of cyclonic storms, and is on the borderline between Koppen's *cfa* and *cfo* types of climate; that is, a constantly moist climate with at least one month having a mean temperature of 64.4° F. May, June, and July have an average mean rainfall of over three inches per month, and all others over two inches. Thus during the growing season over half the annual amount of rain falls.

The three warmest months are June, July, and August. The combination of rain and high temperature assures a good growing season. Decreasing rainfall in August and fore part of September and the high temperature permit a successful harvest season in the adjoining farming regions.

Because of the proximity of Lake Erie, Bellevue and the adjoining regions have a longer growing season than is ordinarily expected. Lake Erie retards the spring and fall. The last average killing frost in the fall is between October 10 and 15. Thus the length of the growing season, 192 to 198 days, combined with the slow cooling in the fall and the slow rise of temperature in the spring encourages the growth of fruit crops such as cherries, peaches, and apples, and near the lake, grapes, which in turn influences the industries of this town.

THE ABORIGINAL FOREST COVER

The early settlers who came to the site of this town called the area immediately to the west the "Oak Openings," where the larger forest trees were really "few and far between" and mostly white oak and hickory. The undergrowth consisted of small hickory, scrub oak, sassafras, spice, hazel, huckleberry, and alder. In the rest of Sandusky County the forests were generally made up of "white, black, red, scarlet, bur and pin oak, white and red (slippery) elm, white, black and blue ash, common and big shellbark hickory, smooth hickory, white and yellow poplar, cottonwood, linden (basswood), sugar maple, beech, black and white walnut, soft maple, buckeye, sycamore, hackberry, honey locust, willow, and iron wood," with only a little difference between the stock of higher and of lower, wetter land (5). Chestnut was found in few places, usually on the beaches. Maumee beach was called "Butternut Ridge" by the settlers because of its numerous butternut trees. This region is a transition between the Southern Hardwood (oak-hickory forest), and the Southern Chestnut (chestnut, oak, yellow poplar forest). The climate was warm enough to permit both types and the sandy soils favored the latter. The amount and distribution of the rainfall with the maximum in the summer and the long growing season explain the large size of some of the forest trees.

The area immediately to the east was called the "Prairies." This was formerly a part of the Maumee Lake Bed. The surface is remarkably level and underlain with a very fine soil. Consequently, this area is alternately too wet and too dry for the growth of trees except where locally a more porous soil prevails. As a result few trees grew, and prairies prevailed.

Many early settlers upon entering the "Prairies" and the "Oak Openings" judged that the soil was not fertile enough to produce crops because it did not produce many trees and so passed on to more heavily timbered country, expressing their regret after their mistake had been proven.

EARLY HUMAN OCCUPANCE

Landscape During the Indian Period—The area around Bellevue was occupied for an indefinitely long time before the appearance of white men. Burial mounds are found at various places in Sandusky County, usually along streams and beaches. One such mound was opened a few years ago by museum authorities within one-half mile of the west town corporation line. Because of the character of the remains in the mound and the imperfect construction of the earthworks scientists claim they belong to the Eries who were exterminated in the early 16th century by the Iroquois. These lands remained little more than hunting grounds for half a century or more until the Wyandots, Ottawas, and remnants of other dispersed tribes regained some power and returned. The Indians settled near the lake and streams and used the adjoining lands for hunting. Judged from the numerous arrowheads, tomahawks, and other Indian relics along the beach ridges these must have been used as trails, probably chosen because of their superior drainage.

The Indians depended on the indigenous wild life leaving the forest cover little altered. The prairies were burned over each fall because the deer were more easily tracked and hunted over the bare and blackened soil. They tilled some soil in a superficial way and often had short crops. The Indian was primarily a hunter and a tribal warrior until an overpowering enemy, the white man came. Because he exploited only the wild life of the forest and streams, which is almost non-existent today, he was semi-nomadic. He built no enduring institutions or lasting establishments. All there is left are a few earthworks or Indian mounds, arrowheads, charcoal, fish or clamshell heaps and place names adopted by the white settlers.

Although the Indian occupance of the land was only semi-permanent it retarded the settlement of white men until treaties had been consummated with the United States government. In spite of these treaties the Indians desultorily occupied this territory and reluctantly gave up their hunting grounds.

Indian Removal and Survey Period—The story of the gradual encroachment of the white settler upon the Indian lands was the same as usual on the American frontiers. Ceding by the Indians began in 1785 when a two mile square in Sandusky County was acquired to build Fremont. Roadways 120 feet wide and adjacent farm lands were next granted. Cession was sometimes made for cash. In 1807 Surveyor Tappan wrote that all the Indians (Wyandot, Ottawa, Chippewa, Munsee, Delaware, Shawnee, and Pottawattamie tribes) had evacuated this tract of over three and a quarter millions of acres (3,366,000 acres).

Following the Indian removal from the "Firelands" the territory was occupied for about two years only by the surveyors of the Connecticut Land Company. The western boundary of the Connecticut

Reserve was run a little west of north instead of due north so that some of the springs north of Bellevue could be included. The drawing which established the ownership of these lands took place in November, 1808. Very few, if any, of these owners ever lived upon their lands. Thus during the interim between the time of the Indian removal and the white settlement there was little or no change in the landscape.

The owners then subdivided the land and sold parcels to the individual settlers who often selected the land after they arrived. On February 12, 1820 "The New Purchase" (lands west of the Connecticut Reserve) was carved into 14 counties of which Sandusky was one.

The Indians, The Connecticut Land Company, the late survey of the lands west of the "Firelands," and the War of 1812 retarded settlement in this part of Ohio until much later than in southern Ohio. The exceptionally cold summer of 1816 with frosts in New England every month stimulated their settlement.

Pioneer Settlement in Pre-railroad Days—In 1815 the first settler of Bellevue, Mark Hopkins, of Genessee County, N. Y., located with his family on Maumee beach about one-fourth mile from the eastern boundary of the town. In February, 1815, John Baker, from Cortlandt County, N. Y., located about two and one-half miles northeast from the first cabin. The first settlers drove their ox teams along the trails which followed the higher and better drained beach ridges to the sites of their respective farms. Much of the surface of the Lake Plain was marshy and as a consequence the beach ridges and the sand dunes directed the pattern of settlement.

When Bellevue was on the western fringe of settlement the first settlements were in scattered isolated clearings of the wilderness. Simple cabins of the rough-hewn, abundant logs with chimneys of stone and mud, and "shake" roofs formed the homes for the first settlers. The first crops of corn and forage were often raised among the stumps of hastily cleared land. With the abundance of wood and the necessity of speedy clearing men resorted to fire as the cheapest and easiest way of preparing the land for agriculture. Log rolling, where logs were cut and stacked into great piles, and burned, were so numerous and essential that they became a part of the social life of the pioneer. Rapidly the landscape changed into the rectangular, open fields waving with grain and dotted with woodland.

Subsistence farming was necessarily the most important occupation of the period. Corn, wheat, oats, potatoes, and vegetables were planted in the cleared spaces. Sheep and cattle grazed on the swamp land and the prairies until sufficient land had been cleared of trees and underbrush.

Hunting was another important employment of the early settlers and often supplied the greater amount of their subsistence. It was customary for families to live several months on a meat diet with no bread. Furs were used instead of money.

The forests furnished materials for the pioneer's home, furniture, tools and fences. The fruits, berries, nuts, wild honey, and the maple sugar were some of the important and needed products of the forest. The burning of deciduous hardwood furnished "black salts" often concentrated into "pearlash" or potash. This ash supplemented furs for money. With these the pioneers bought salt, rifles, iron, cotton clothing, tea, and paid their taxes. The pioneer, unlike the Indian who depended upon the gifts of nature for a livelihood, exploited the forest and the soil.

Of necessity most of the manufacturing was done in the home; clothing, farm tools, candles and furniture. Every household was more self-sufficient than any of later date. In 1823 Nathaniel and Fred Chapman established the first retail business to supply some things that could not be made. The first manufactories to come were the grist and the saw mills usually run by little water powers. These depended upon the products of forest and soil. The settlers of this streamless sink hole area had to go east to permanent streams to set up their mills. Even here water wheels were not very dependable because of the freezing in winter, the level topography, and the occasional droughts. The first mill in this area was built in Lyme Township in 1818.

Blacksmithing, an industry necessary to the farmer settler was established here as early as 1817 and another quickly followed. The smiths not only shod horses but made axes, hammers, carts, harrows, all of a plow except the mold board, and many iron articles.

There was little surplus or sale of farm products. Transportation from this region was too difficult. The ox teams which were generally used were driven along the old Indian trails following the higher beach ridges to Lower Sandusky, (now Fremont) a trading post. Few bushels of wheat and corn followed this route, until 1825 when the Erie Canal opened a world market.

Early in the history of Bellevue the farmer pioneer settlers recognized the need of taverns on this beach ridge which led to the west. The first hotel (1816) was a log cabin standing near the center of the present town. Because of the nature of the roads taverns were numerous and travelers occasionally stayed at the same tavern two nights in succession, especially during spring rains.

Roads and Settlement—The early roads followed the Indian trails along the better drained beaches. The Maumee and Western Reserve Turnpike, a military road 120 feet wide, was built on a grant of land to extend from the Maumee River to the western boundary of the Connecticut "Firelands." Other roads crossed and fed travelers into this turnpike.

The Embryo Village—In 1824 this military road which had been ceded to the state of Ohio was laid out and established on its present line, with its eastern terminus at the Strong's Ridge road. This was the starting point for Amsden's Corners named for the settler who kept the tavern. When the north and south road came here the settlement was called York Cross Roads. It grew to the present Bellevue.

The Kilbourne Road was ultimately routed through York Cross Roads and stimulated its growth. It was followed by the route to Cold Creek or Castalia.

Strong's Ridge Road was preceded in the early years by the winding Indian beach trail. Later, in order to straighten the road to its present line, artificial gradings were made. In the unplanned town the higher, better drained, and more level land had been used for roads and home sites.

Bellevue Surveyed and Laid Out—In 1835, fifty acres on the Huron County side was laid out in village lots of varied sizes and prices, the average being one-quarter acre for $50. In 1839 land on the Sandusky County side was surveyed and laid out. These lots were somewhat larger and in order to get settlers prices were lowered, terms were made easier, and speculators were discouraged. The town of Bellevue was incorporated January 25, 1851.

The settlers of these early days were of four different strains as shown by their names. The New York and New England influence is represented by the Woodwards, Sheffields, Bakers, and Woods; the Pennsylvania Dutch by the Kerns, Leibachs, Hetters, and Wolfslagels; the English element by the Heals, Willses, and Potters; and the German strain by the Bollenbachers, Liebers, Ruffings, and the Biebrickers. In recent years Italians and a few negroes have been brought in by the railroads as a cheap labor supply. The best property and positions are held by people of the first four strains.

THE RAILROAD STAGES

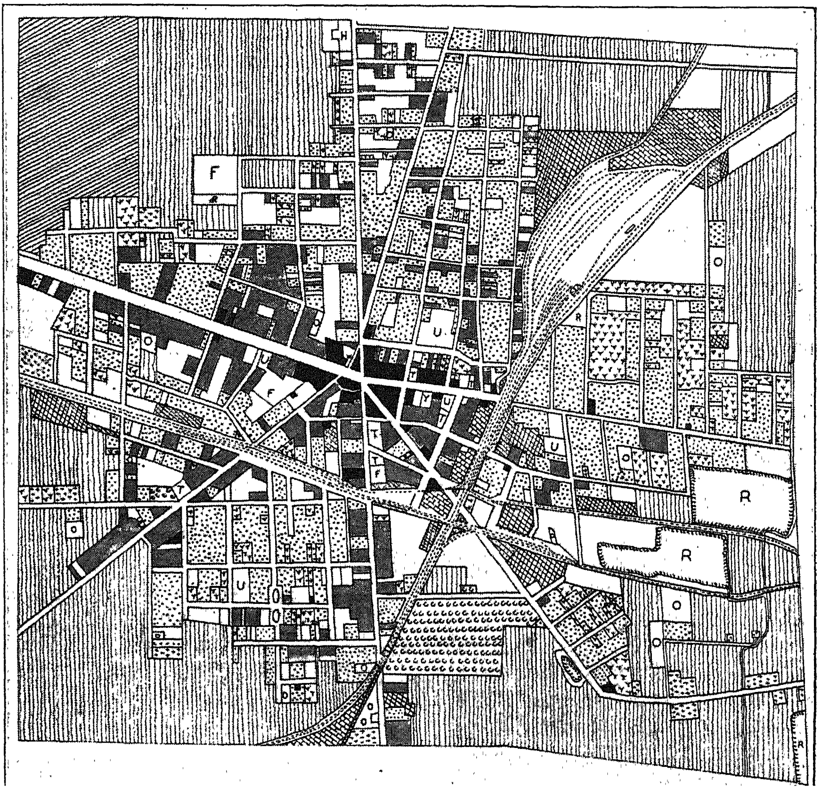
The Coming of the Railroad—The present history of the town is closely connected with railroad development. James H. Bell, a civil engineer of the Mad River and Lake Erie Railroad named this station Bellevue which suggested his name and his judgment of the site. This railroad was extended to Tiffin in 1841 and later to Springfield. In 1855 this route, from Sandusky to Tiffin, was changed to go by way of Green Springs and Clyde instead of Bellevue, but another railroad came soon.

In the early year the railroad was considered by most people as a great promoter of business because of the widened markets for the community through which it passed. As soon as the Toledo, Norwalk, and Cleveland Railroad was incorporated in 1852, Sandusky County voters authorized that $50,000 of its stock be purchased. The road was completed in 1853. Today it is known as the Lake Shore and Michigan Southern Division of the New York Central.

After the coming of the railroad the growth of the town was steady and continuous. Shops and business establishments were erected. Population increased so that in 1869 the corporation limits of the town were enlarged from a mile east and west along Main Street and extending one-fourth of a mile north and south of this street to a mile and a half square. The town was still equally divided between the two counties. When Bellevue was incorporated the population was about 800, in 1873 it was about 3,500. Today it is over 6,800.

BELLEVUE TODAY

Bellevue, a compact settlement, is almost square. Because of the convergence of the main route which followed the ridge the Western Reserve Maumee Pike with the routes which come from the Lake Plain and because of the diagonal railroad routes which cross the town and intersect in it, Bellevue could be called a town of many angles. The Strong's Ridge road which followed Center Street was straightened to the present line of Main Street. This explains the awkward angle by



LAND UTILIZATION MAP
OF
BELLEVUE, OHIO

---

which Center Street comes into Monroe Street. Today the Huron side of Bellevue has a majority of the people because of its early start and because it was favored by the railroads. With the exceptions of the quarry and the Bellevue Manufacturing Company, industries and their laborers following the railroads, are located on the Huron or eastern side of the town.

The residential sections of the town are generally attractive. The better homes and broader lawns are located along the main streets away from the railroad and on the higher land west of the center of town. Along the Maumee Pike the strip of lawn between the curb and sidewalk is exceptionally wide, 20 feet on each side, because of the original land grant, and because of the broad, better drained beach ridge and dune area. The predominance of small homes, narrow lots, and well kept kitchen gardens proclaim a middle class population living comfortably on modest cash incomes. Most of these yards are planted with fruit trees and vines. The dilapidated homes of the Italian population along the Nickel Plate Railroad and southeast of the center of the town are not so attractive, with tiny lawns, the narrower lots, and proportionally larger kitchen gardens. In the backyards of most of these homes may be seen a small chicken house and few rabbit hutches fitting snugly beside a family garage. The only vacant houses in town in 1939 were two in this section.

Styles in architecture are extremely varied. The older, larger homes are in an ornate style, prevalent during the 80's. Three large limestone houses, two on Southwest Street and one on the Maumee Pike, date from the 30's, and reflect the proximity and durability of the limestone. Most of the homes are small, from one to two story frame structures to which rooms have been added as occasion has required and are a response to the cheapness of land and modest incomes. But few homes are of recent construction, suggesting the extremely slow expansion of population.

About 80 per cent of the Bellevue residences have limestone foundations. Brick, tile, or cement foundations of recent buildings indicate the attachment to local, serviceable, cheap, materials. Over 90 per cent of the sidewalks are of the Berea sandstone flagging which fact attests the relative cheapness of transportation from the Amherst Quarries 40 miles away during the development of this town.

The main roads of the town are brick of local clays, while many of the side streets are of crushed limestone.

The nucleus of the retail district is in the central part of the town, the "Corners," on Main Street for about four short blocks and a few doors down each of the side streets of this section.

The buildings of the retail district are not distinctive; one to two story brick or frame structures give a low profile and emphasize the relative cheapness of land. Salesrooms are on the first floors, professional and living apartments or storage rooms on the second. The neat stone fronts of the recently built bank buildings near the center of the town add a welcome note of modernity.

The merchandizing establishments are of the usual types: groceries, meat markets, furniture, clothing, dry goods stores, auto supply shops, hardware and dime stores, shoe repair shop, drug stores, a news stand, feed stores, and garages with sales rooms for the popular and inexpensive automobiles. Five one-room groceries, often a room in a private home located from three to six blocks from the center of town, are a convenience for the local residents. The town possesses two movie houses. One runs but three days a week because the modern means of transportation encourage competition with the cinemas in Fremont, Norwalk, and Sandusky each about 15 miles away. The hardware store, handling farm implements extends its influence into surrounding agricultural regions. A barn for the storage and display of implements is located on cheap lands near the Nickel Plate Railroad. Filling stations occupy many of the corners in the town, especially those bordering state route No. 20, where heavier traffic runs.

Much expense and effort have been given to the cultural needs of the community. There are six school buildings, five of which are grade schools and scattered throughout the town. One parochial school is situated within two blocks of the nucleus of town. The public schools in the eastern and southern parts of town are farthest from the center (4½ and 5½ blocks). All school buildings are brick structures.

Eleven different Christian denominations are represented in this town: the Catholic, Lutheran, Baptist, Episcopal, Reform, Congregational, Christian Scientist, Methodist, Evangelical, Church of The Nazarene, and The Church of God. The Catholic, Lutheran, Evangelical, and Reform churches are of brick, the Episcopal Church uses the durable, attractive limestone from the Bellevue quarry. The Congregational Church is a solid Ohio sandstone structure. The Baptist Church is a frame building. An attractive but scarcely durable stucco covering has been put on the Methodist and Christian Scientist Churches. The Church of The Nazarene and The Church of God are of more recent origin and thus occupy a room in commercial blocks in the retail section. The churches, with the exception of the Reform Church, are convenient and accessible. Each is on a main street, except the Baptist Church which is a half block north of Main Street.

Recreational facilities are found at the Y. M. C. A., in a large park used for baseball and other outdoor sports out where land is cheap; the high school stadium on the low level land just south of the sand dunes along Main Street a block west of the center of town.

On the outer zones of the residential and industrial sections of Bellevue is an irregular zone of agricultural land. This illustrates the relative cheapness of land within the corporation. Fifteen farmsteads are found within the town limits. Corn, small grains, hay, and pasture are the most popular crops. A small percentage of this outer zone remains vacant and unproductive, because of sink holes and the consequent poor drainage during the rainy season.

The railroads are the most important industry of Bellevue. The Lake Shore & Michigan Southern and the Wheeling and Lake Erie divisions of the New York Central cross in an east-west direction in the southern half of town. The Pennsylvania, only a freight road, the Nickel Plate Railroad (New York, Chicago, and St. Louis division) enter the town from the northwest and continue south, and the latter turns and leaves the town at the southwest. Their depots are within two or three blocks of the center of town. The Nickel Plate has a terminal here for one division because Bellevue is situated on the level Lake Plain on the important transportation lines between large industrial centers of the country, and because it has plenty of land to offer railroads.

Approximately 650 residents work for the railroads in shops, yards, and on train service. Because the railroads consume about half the total town supply of water much anxiety is felt during dry years, such as 1934 and 1939.

The importance of the railroads may be estimated from the large amount of land in the town utilized by this cultural feature. They have cut diagonally across the town, disturbing the streets of the town and the property lines. On East Main Street (State Route No. 20) the motor traffic was often stopped by the numerous trains. Because of the continual loss of time and the inconvenience experienced, as well as a terrific accident, at this crossing, a subway bridge was completed in 1938. The railroads go over the motor road. Work was suspended for some time during the spring of 1936 because the excavation was completely submerged. In order to keep this depression free of the surface water after an ordinary rain, a $7,000 electric pump has been installed to pump the water from the subway to adjoining sink holes.

Three mills stand beside the Lake Shore and Michigan Southern R. R. and the Wheeling and Lake Erie R. R., one at the intersection of these railroads with the Nickel Plate. Farmers of the surrounding area often sell their surplus grain at these mills and bring grain to be ground for stock food. Sometimes the mill ships this surplus grain by railroad or truck to larger markets, such as Cleveland. Lumber and coal yards are all near a railroad.

Two bakeries and four creameries are the chief subsistence industries. The dairies buy most of their milk from the farmers of the surrounding regions. Trucks collect it each day and bring it to the plants which are within the town, with one exception, where it is made ready for retailing. Each dairy does not employ more than half a dozen men.

Bellevue industrial establishments are not as much local necessities as in early days, but they are dependent on local products or market. Several are distinctly seasonal. A cherry cannery and a kraut and pickle company join with a pork packing company in the employ of 250 workers and the use of tons of sand dune cherries, beach cabbage and cucumbers, and many hogs of nearby farms. Bellevue and many of the nearby towns are supplied by means of delivery trucks with the products of these companies.

The Ohio Cultivator Company, employing about 200, meets the surrounding agricultural needs and makes use of two railroads.

Two companies manufacture iron and steel products, for a wide market, particularly through General Motors, Incorporated. All these industrial plants are near railroads and together give to Bellevue an industrial flavor and a smoky sky line or profile.

Public utilities, some of them privately owned, and the town newspaper give employment to nearly 20 people.

The France Stone Company is located at the limestone quarry on the northwestern edge of town. This quarry has been operated since early days; as a result, it is well into its second level cut and approximately 45 feet deep. About 150,000 tons of rock are quarried annually. Most of this is used for road materials for the surrounding areas. Other uses are for flux out of town, land lime on farms, and concrete blocks mostly in town. Because of the proximity of the quarry and the consequent cheaper transportation, the city is planning to use some of this stone for re-enforcing the walls of the reservoirs. Approximately 25 men are employed in this industry.

Bellevue depends upon surface water. Three large reservoirs, with combined capacity of 295,000,000 gallons, are located on the eastern side of the town. During dry years, such as 1934, this surface supply is not sufficient. A well 165 feet deep, with harder water, is then drawn upon, and the sprinkling of lawns and gardens is forbidden. In the fall of 1936 a new purifying plant was established near the middle reservoir, to insure a more healthful water. During an early period of growth the citizens of the town rejected a plan to get the town's water from Lake Erie. This vote has been regretted by many because the present water is harder than lake water with many chemicals in it which are detrimental to pipes and hot-water heaters, and the supply has been so limited in dry seasons that the chief industry of the town, the Nickel Plate Railroad, has threatened to remove its terminal.

The system for the disposal of sewage in Bellevue is unique. Natural and artificial sink holes are relied upon entirely. One natural sink accommodates as many as 12 houses, while an artificial sink accommodates from one to three. When an artificial sink is made, a well-driller bores a hole through the limestone bedrock until a wet crevice is reached. The city fire department is then called upon to test it. Water is poured down it and if the crevice can take the water as fast as it is given, the hole is pronounced satisfactory; if not, the well-driller continues to a crevice which does prove satisfactory. When the hole is found satisfactory, a perforated 6-inch iron pipe is inserted into the top and an area about 5 feet across and 10 feet deep is cemented or bricked for a cesspool. The perforated iron pipe has a plunger which can be worked occasionally without removing the heavy cement cover of the sink hole. Thus some of the surface wash and large articles are prevented from filling it up. However, frequently sink holes become choked with sediment and the owner of the property is burdened with the expense of re-drilling the hole. The deepest drilled sinks are found northwest of town around Euclid Avenue. A common depth is around 60 or 70 feet.

During the season of spring and fall rains the sink holes are not sufficient. The streets in the lower sections of the town are often flooded for several hours at a time and basements then have from one to three feet of unclean water at a time.

In 1913 and 1936 the spring rains in this and bordering regions to the south were exceptionally heavy. As a result, many of the sink holes became fountains and the surrounding areas became lakes. The water was six to twelve feet deep in some streets in the southern part of town. Here currents of considerable force caused damage to lawns and property. Depressions not more than a foot across and a few inches deep developed into holes 20 feet or more across and three or four feet deep during these floods. The present sink hole method of handling the sewage is a menace to public health. Consequently, an order from the State Board of Health to install a sanitary sewage system may end it at any time.

The citizens of Bellevue are aware that the water supply problems and sewage disposal system are of growing importance. It is probable that in the near future Bellevue may draw upon Lake Erie for a better and more dependable supply of water.

Immediately to the west of Bellevue a settlement of a semi-rural character follows the ridge and well-drained sand dune area bordering the Maumee Pike. Because of their proximity most of the inhabitants consider Bellevue their chief shopping center.

Bellevue occupies a favorable position with relation to population centers of the United States which furnish markets for the manufactured and quarry products. The numerous railroads and hard-surfaced motor roads form excellent regional connections with these markets. Trucks do a large part of the hauling.

The metropolitan influence of Cleveland, Sandusky, and Toledo, may be seen in various features on the local landscape. The greater volume of traffic (especially the preponderance of freight traffic between Toledo and Cleveland) on the roads leading to these cities suggests their nearness and market value. Because of the proximity of these cities and excellent transportation facilities, their newspapers are distributed daily in Bellevue. The metropolitan influences are not all particularly beneficial. Local retail merchants as well as the chain stores depend upon the wholesale concerns in Cleveland and Toledo for their supplies because the improved transportation facilities allow this. The retail dry goods stores carry a limited stock of goods because much shopping is done in these larger cities. Shopping News from Cleveland is distributed weekly.

CONCLUSION

Bellevue resembles in history and development many towns of Ohio. It differs from a large number in having, especially in its early decades, a good roadway along the several old beaches. Beach towns, though on abandoned beaches, are quite different commercially from lake towns. Bellevue is unique in its water and sewage developments. Other towns along the north-south sink hole belt might have similar problems, but there were no other beaches across this belt to call for towns, hence Bellevue can be called unique in location and in its peculiar adjustments to its unique situation.

BIBLIOGRAPHY

(1) **Baughman, A. J.** History of Huron County, Vol. I. S. J. Clarke Pub. Co., Chicago. 1909.

(2) **James, Preston E.** The Terminology of Regional Description. Assoc. American Geog. XXIV, 78–92. 1934.

(3) **Jones, Wellington D.** Procedures in Investigating Human Occupance of a Region. Assoc. Amer. Geog. XXIV, 93–112. 1934.

(4) **Kemp, Harold S.** Queen City of the Lakes, A Geog. Pageant. Jour. Geog. XXX, 93–110. 1931.

(5) **Meek, Basil.** 20th Century History of Sandusky County, Ohio, and Representative Citizens. Richmond-Arnold Pub. Co., Chicago. 1909.

(6) **Orton, Edward, Jr.,** and **Samuel V. Peppel.** Limestone Resources and Lime Industries in Ohio. Geol. Survey, Ohio 4th Series, Bull. 4. 1906.

(7) **Read, M. C.** Geology of Huron County, pp. 289–309, Geol. Surv. Ohio; Vol. III, Part I. Columbus, Ohio. 1878.

(8) **Whittlesey, Derwent.** Metropolitan Districts, Population and Area. Jour. Geog. 32, 334–337. 1933.

(9) **E. F. Warner.** Pioneer Days and Settlement: The Makers of Sandusky County, pp. 98–145.

(10) **E. F. Warner.** Bellevue Village and York Township, pp. 350–355.

(11) **N. H. Winchell.** Geology of Sandusky County, pp. 591–610, Geol. Surv. of Ohio; Vol. I, Part I. Columbus, Ohio. 1873.

Physiological Chemistry

The sixth edition of this text is a revised, enlarged and up to date version of biochemistry. It is presented from a broad biological viewpoint and in a manner which arouses the student's interest by challenging his scientific imagination.

The book is ideally suited to the needs of medical students in its selection, arrangement and emphasis of material. Its greatest asset, however, is that it leaves the medical student with an integrated picture of the various phases of body chemistry and thereby provides him with a basis for understanding later courses in normal and pathological physiology and the rationale of therapy.

The section on Laboratory Methods has been omitted from this edition and has been published separately by The Williams and Wilkins Company as "Practical Methods in Biochemistry" by F. C. Koch.—*M. M. Parker.*

Physiological Chemistry, Sixth Edition, by Albert P. Mathews. xvi+1488 pp. Baltimore, The Williams and Wilkins Co. 1939. $8.00.

BLACK WIDOW SPIDER (LATRODECTUS MACTANS FAB.) DISTRIBUTION IN OHIO

FRANK MERRICK SEMANS
Youngstown College

In the winter and spring of 1940 the author made a survey of the distribution of the black widow spider (*Latrodectus mactans* Fab.) in the state of Ohio from his records and from those of nearly forty collaborators—biologists and naturalists from all parts of this state.[1] A summary shows that specimens have been reported from thirty-two counties, although prior to this survey, specimens had been reported from but three counties.[2] The black widow spider is limited in its distribution in Ohio to the eastern and southern sections and is not found more than twenty-five miles beyond (i. e., to the west and north) the borders of the hilly area (the unglaciated Allegheny Plateau and the eroded Ohio River region of southwestern Ohio)—an area with fairly even black widow spider distribution, bounded in general by the Ohio River from Cincinnati to East Liverpool and beyond to Youngstown, on one hand, and by the following cities on or near the margin of the hilly region of the state, on the other, Hamilton, Chillicothe, Lancaster, Newark, Mt. Vernon, New Philadelphia, Youngstown.

The author, who is collecting spiders in eastern Ohio, has found in this area black widow spider specimens largely under small, loose rocks which have become shelved through soil erosion, on dry, bare hillsides, or under objects on well-drained, sandy soil; collaborators have reported similar experiences, the exception usually being a building where the spider has found similar conditions. As the western Ohio prairie region and the relatively level northern part of the state apparently do not have this spider, it seems logical to conclude that the black widow spider prefers the dry surroundings afforded by areas that have rapid water drainage.

---

[1] An exhibit including map and legend was presented at the Semi-Centennial Celebration of the Ohio Adcaemy of Science in the spring of 1940.

[2] Barrows, W. M. 1918. A List of Ohio Spiders. O. Jr. Sci. 18, No. 8: 303.

NINE NEW COLEOPTERA

(PLASTOCERIDAE, BUPRESTIDAE AND CERAMBYCIDAE)

JOSEF N. KNULL
The Ohio State University

Plastocerus jeffersonianus n. sp.

Male.—Narrow elongate, pronotum, and entire ventral surface including legs yellow. Head, antennae and scutellum dark brown, elytra black.

Head convex, front depressed; surface densely coarsely punctured, pubescent; eyes prominent hemispherical; antennae reaching to basal portion of elytra when laid along side of pronotum, scape stout, second joint wider than long, third joint same size, fourth joint longer than wide, following joints increasing in length, eleventh joint longest, joints four to ten inclusive with appendages, length of outer modified parts nearly three times length of segments, joints densely pubescent.

Pronotum about as long as broad, widest at base, constricted at apex; sides nearly parallel at apex, expanded at middle, sinuate at base, hind angles divergent; disk convex, prehumeral and lateral marginal carinae absent; surface coarsely punctured, punctures slightly smaller than those of head, pubescence of same length and density as that of head. Scutellum rectangular, depressed in middle, densely finely punctured.

Elytra wider than pronotum, widest at base; sides rounded in front, constricted about middle, apices acutely rounded; disk convex; surface striate, punctures of striae larger than those of pronotum, interspaces convex, finely punctured, punctures same size as those of scutellum, pubescence same length and density as on pronotum.

Abdomen beneath densely finely punctured, punctures more numerous on last segment, pubescence same length as on elytra, last segment acutely rounded. Prosternum coarsely punctured, a transverse carina in middle, posterior median carina lacking. Hind tarsi long, shorter than tibiae.

Length 9.7 mm.; width 2.6 mm.

Described from specimen in the collection of the writer taken in the Davis Mountains, Jeff Davis Co., Tex., July 2, 1940, by D. J. and J. N. Knull.

According to Van Dyke's key[1] this species would run to *P. granti* Schffr. It can be separated by the color and lack of longitudinal median prosternal carina.

Plastocerus coronadi n. sp.

Male.—Elongate, dark brown with exception of abdomen which is yellow.

---

[1] E. C. Van Dyke, Proc. Cal. Acad. Sci., v. 10, No. 9, pp. 1–465, 1932.

Head convex, coarsely, densely punctured, densely pubescent; eyes prominent, hemispherical, antennae reaching to basal portion of elytra when laid along side of pronotum, scape stout, second joint broader than long, third joint as long as broad, fourth joint longer than third, following joints increasing in length, eleventh joint longest, constricted near tip, joints four to ten inclusive with appendages, length of outer modified parts over three times length of segments, joints densely pubescent.

Pronotum as long as broad, widest at base, apex narrower; sides rounded in front, parallel to near base, hind angles divergent; disk convex, prehumeral carinae rather indefinite, lateral marginal carinae extending full distance; surface coarsely densely punctured, punctures separated by less than their own diameters, same size as those of head, pubescence of same density as on head. Scutellum nearly square, depressed vertically, punctures same size as elytral interspaces.

Elytra much wider than pronotum, widest at umbone; sides rounded in front, slightly constricted about middle, apices acutely rounded; disk convex; surface striate, punctures of striae half the size of those on pronotum, interspaces convex, granulate, densely punctured, punctures smaller than those of striae, pubescence of same density as on pronotum only shorter.

Abdomen beneath densely finely punctured, punctures more numerous on last segment, pubescence same length as on elytra, last segment broadly rounded. Prosternum coarsely punctured, a prominent median carina in rear joining a transverse carina in middle. Hind tarsi long, shorter than tibiae.

Length 12.6 mm.; width 3 mm.

Described from four male specimens collected in Lincoln Co., N. M., July 19, 1940, by D. J. and J. N. Knull. Type material in collection of writer.

Variations.—One paratype has a yellow prothorax.

According to Van Dyke's key[1] this species would run to *P. megalops* Fall. It can be separated by the color and smaller eyes.

Agrilus cliftoni n. sp.

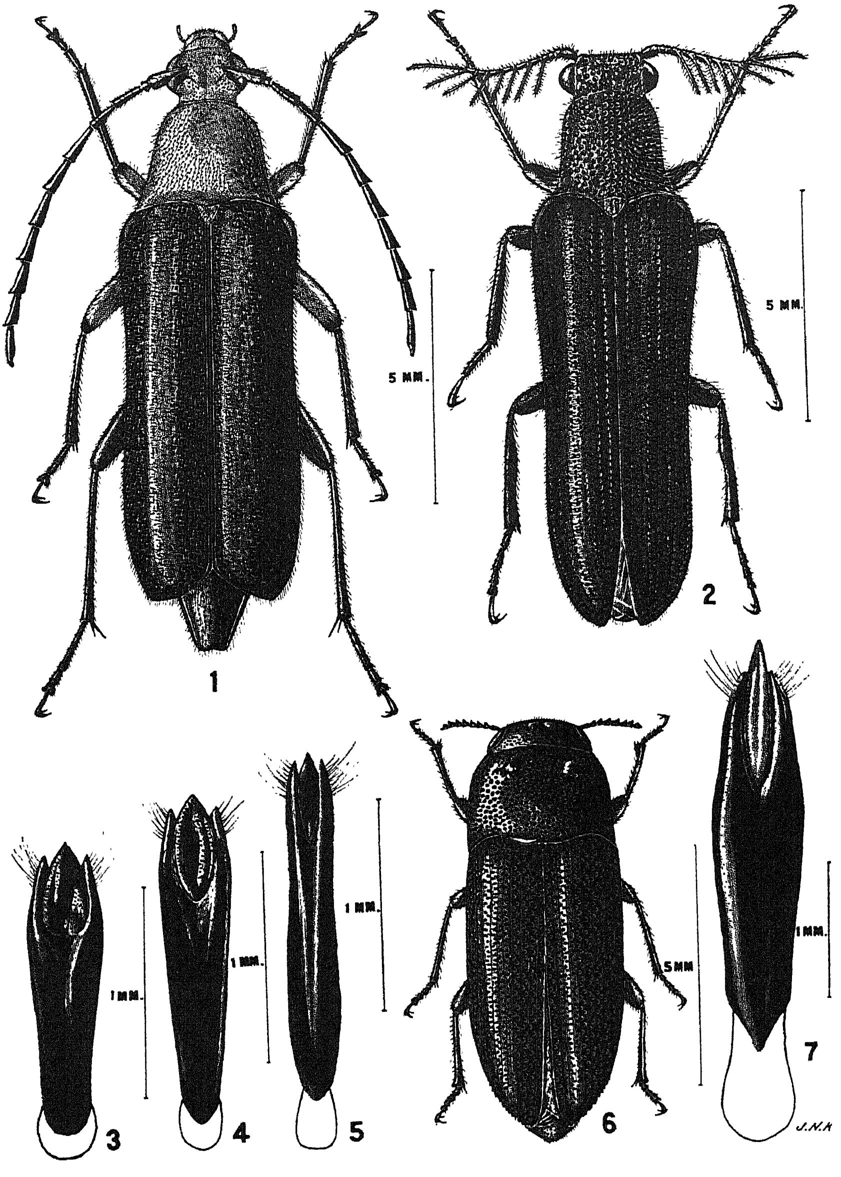
Male.—Resembling *A. masculinus* Horn in size, form and color; antennae, head, pronotum and legs bronzy green, elytra piceous with bronzy lustre, beneath dark bronze.

Head convex, with slight median depression on vertex; surface granulose on front, vertex coarsely punctate; antennae not extending to middle of pronotum when laid along side margins, serrate from the fourth joint.

Pronotum wider than long, wider at apex than at base, widest in front of middle; sides arcuately rounded in front, then obliquely narrowed to base; when viewed from the side, marginal and submarginal carinae separated in front, joined near base; anterior margin strongly sinuate, median lobe broadly rounded; base transversely bisinuate, median lobe not produced and arcuately emarginate in front of scutellum; disk convex, with two median transverse depressions, a lateral depression each side, prehumeral carinae well defined; surface densely

New Coleoptera
Josef N. Knull

PLATE I



1. *Euryptera texana* n. sp.
2. *Plastocerus coronadi* n. sp.
3. Male genitalia of *Agrilus davisi* n. sp.
4. Male genitalia of *Agrilus patagoniensis* n. sp.
5. Male genitalia of *Agrilus cliftoni* n. sp.
6. *Hippomelas pygmaea* n. sp.
7. Male genitalia of *Hippomelas femorata* n. sp.

transversely rugulose, fine punctures between rugae. Scutellum transversely carinate.

Elytra at base wider than base of pronotum; sides parallel near base, constricted in front of middle, expanded back of middle, apices rounded, serrulate; disk convex, sutural margins elevated back of middle, basal depressions prominent, an obsolete costa on each side; surface imbricate, pubescence not distinct.

Abdomen beneath coarsely punctate, first two abdominal segments only slightly flattened, lateral margins of first two adbominals distinct; pygidium without projecting carina. Prosternal lobe declivous, deeply emarginate in front; prosternal process wide, sides parallel to behind the front coxae, then obtusely rounded. Tibiae of first two pairs of legs mucronate on inner sides at apices, posterior tibiae not mucronate. Posterior tarsi not as long as tibiae, first joint not as long as the following joints united. Tarsal claws cleft at middle, outer tooth acute at apex, inner broader and turned inward, tips touching, claws similar on all feet.

Length 5.7 mm.; width 1.4 mm.

Described from one male specimen collected at Clifton, Ohio, May 30, 1939, by D. J. and J. N. Knull, in the collection of the writer.

According to Fisher's key[2] this species would run to *A. arcuatus* (Say), however the genitalia will serve to separate it.

Agrilus patagoniensis n. sp.

Male.—Robust, dark cupreous above and below; head, sides of pronotum and a vitta on each elytron clothed with white recumbent pubescence.

Head deeply impressed; surface coarsely, densely punctured, rugose; antennae reaching to beyond middle of pronotum when laid along side margins, serrate from the fifth joint.

Pronotum about as long as wide, wider at apex than at base; sides nearly straight, narrowed posteriorly; when viewed from the side the marginal and submarginal carinae are united at base; anterior margin sinuate, median lobe broad; base strongly emarginate at middle of each elytron; disk convex, lateral depressions deep, a broad transverse depression at base, prehumeral carinae tuberculate, not sharp; surface coarsely transversely rugose, finely punctured between the rugae. Scutellum glabrous, lacking transverse carina.

Elytra at base as wide as base of pronotum, widest back of base; sides nearly parallel at base, constricted at middle, widened back of middle, apices rounded, serrulate; disk convex, sutural margins elevated back of middle, basal depressions deep, surface coarsely imbricate.

Abdomen beneath finely punctate, clothed with recumbent white pubescence; first and part of second segment flattened at middle; pygidium without projecting carina. Prosternum densely punctured, pubescent, pubescence extending along median line to second abdominal; prosternal lobe broadly rounded in front; prosternal process expanded back of coxal cavities. Tibiae on first two pairs of legs mucronate on inside at apices. Posterior tarsi slightly shorter than tibiae, first joint shorter than the three following joints together. Tarsal claws cleft, the inner teeth not turned in, posterior tarsi with inside teeth much shorter than outer ones.

---

[2] W. S. Fisher, U. S. Nat. Museum Bul. 145, pp. 1–347, 1928.

Length 7 mm.; width 1.8 mm.

Female.—Tibiae not mucronate, middle portions of first two ventral abdominal segments convex.

Holotype collected in the Patagonia Mountains, Arizona, July 22, 1940, by D. J. and J. N. Knull. Allotype labeled Nogales, Ariz., July 30, 1937, E. D. Ball. Type material in writer's collection.

According to Fisher's key[2] this species would run to *A. felix* Horn, but the smooth scutellum, coarsely rugose pronotum, lack of sharply defined prehumeral carinae and shape of the male genitalia will distinguish it.

Agrilus davisi n. sp.

Male.—Slightly more robust than *A. egenus* Gory; shining cupreous above; bronzy green beneath; front green, a post-median pubescent spot in center of each elytron.

Head convex, narrow median groove on vertex; surface finely granular, rugose on vertex; antennae reaching to about middle of pronotum when laid along side, serrate from the fifth joint.

Pronotum wider than long, wider at apex than at base, widest at apex; sides obliquely narrowed toward base, sinuate near hind angles; when viewed from the side, marginal and submarginal carinae are united near base; anterior margin strongly sinuate, median lobe broad; base sinuate; disk convex, with slight median depression in front of scutellum, lateral depressions strong, prehumeral carinae well indicated; surface transversely rugose, punctures distinct between the rugae, lateral depressions pubescent. Scutellum finely granulate, transversely carinate.

Elytra at base wider than base of pronotum, widest on basal fifth; sides broadly rounded in front, constricted at middle, expanded back of middle, apices rounded, serrulate; disk with sutural margins elevated back of middle, basal depressions well marked; surface imbricate, pubescence inconspicuous.

Abdomen beneath finely punctate, punctures connected by fine transverse lines, pubescence inconspicuous, first segment concave at middle, second segment flattened, pygidium without a projecting carina. Prosternum finely punctate, clothed with long pubescence which extends along median line to second abdominal segment; prosternal lobe truncate. Posterior coxae with hind margin sinuate, exterior angle obtuse and prolonged. Tibiae of first two pairs of legs mucronate on inside at apices. Posterior tarsi not longer than tibiae, first joint not as long as three following joints united. Tarsal claws somewhat similar on all feet, cleft, the inner tooth broad, shorter than outer one and not turned inward.

Length 5.8 mm.; width 1.7 mm.

Holotype collected in the Davis Mountains, Tex., July 1, 1940, by D. J. and J. N. Knull in the collection of the writer.

This species runs to *A. barberi* Fisher in Fisher's key.[2] It may be separated by its more rugose sculpture of pronotum and by the shape of the male genitalia.

Hippomelas femorata n. sp.

Male.—Elongate, robust, dull brassy throughout.

Head convex, coarsely irregularly punctured, punctures finer on vertex, front with median carina flanked by irregular smooth callosities, pubescence sparse; antennae reaching to basal fourth of elytra when laid along side of pronotum, scape not wider than other joints, second joint as long as wide, third joint as long as scape, following joints decreasing to eleventh inclusive, serrate from the fourth joint.

Pronotum wider than long, widest in middle, wider at base than at apex; sides broadly rounded from apex to base; lateral marginal carina inferior in apical fourth; disk convex with two slight depressions on each side in front of humeral angles; surface coarsely, irregularly punctured, spaces between punctures forming irregular smooth areas, pubescence lacking. Scutellum very small, somewhat obscured by pronotum.

Elytra wider than pronotum, widest back of humeral angles; sides rounded in front, constricted in middle, broadly rounded to truncate apices; margins not serrate; disk convex; surface coarsely punctured, punctures smaller than those on pronotum, each elytron with five indistinct costae, giving the elytra a rugose appearance, pubescence short, sparse.

Abdomen beneath finely densely punctured, pubescent; last ventral broadly rounded. Femora of posterior legs stout, tarsi more than half the length of tibiae, second and third joints together longer than first.

Length 11.8 mm.; width 4 mm.

Holotype labeled Potrero, San Diego Co., Calif., Aug. 11, 1940, D. J. and J. N. Knull collectors, in collection of writer.

The narrow elongate form of this insect makes it resemble *Nanularia californica* (Horn). It is quite distinct from other allied forms in its robust femora and the shape of the internal genitalia.

Hippomelas pygmaea n. sp.

Female.—Robust, cupreous above and below.

Head convex; surface rugose, a smooth callosity on front, pubescence short, inconspicuous; antennae short, not reaching middle of pronotum when laid along side margin, scape stout, second joint much shorter, third joint as long as scape, fourth joint shorter than third, following joints decreasing in length to eleventh, joints four to eleven serrate.

Pronotum wider than long, widest basally, constricted at apex; sides broadly rounded in front, parallel on basal two-thirds; anterior margin nearly straight, basal margin trisinuate, median lobe broad; disk convex, a transverse depression in front of scutellum, a smooth callosity on each side in front, lateral margin present on basal half only; surface very coarsely, irregularly punctured, pubescence absent. Scutellum small, triangular, longitudinally depressed in middle.

Elytra wider than pronotum, widest in apical third; sides rounded in front, constricted about middle, broadly rounded posteriorly to rounded apices, margins serrate in apical half; disk convex, a basal depression on each elytron near humeral angle; surface striate, punctures of intervals large, smaller than those of pronotum, irregularly placed, pubescence absent.

Abdomen beneath finely densely punctured, pubescent; last abdominal rounded at apex, surface rugose. Posterior tarsi a little over half the length of tibiae.

Length 8 mm.; width 3 mm.

Holotype labeled Val Verde Co., Tex., June 28, 1940, D. J. and J. N. Knull collectors, in collection of writer.

This species differs from *Nanularia californica* (Horn) by the robust form, lack of pubescence and large punctures on dorsal surface, rounded elytral apices and short posterior tarsi.

Pachyschelus uvaldei n. sp.

Male.—Form and size of *P. laevigatus* (Say); color of head, pronotum and scutellum shining black with slight violaceous reflection, elytra dark violaceous, black beneath.

Head convex, with slight depression on front; surface very finely punctured, punctures becoming obsolete on vertex, void of pubescence.

Pronotum over three times as wide as long, widest at base, narrowest at apex; sides broadly rounded from apex to base, hind angles produced; disk convex, a slight lateral depression at base on each side; surface minutely punctured in center, punctures more numerous along sides, short pubescence along sides. Scutellum triangular, glabrous.

Elytra at base narrower than base of pronotum, widest at base; sides broadly rounded to rounded apices, tips serrulate; disk convex, each elytron with a basal depression and another lateral depression back of umbone; surface with moderate punctures arranged somewhat in rows, each puncture bearing a minute recumbent hair, longer white pubescence in basal depressions of each elytron, a median diagonal band broken at the middle and a diagonal band at apical third which does not run to suture.

Abdomen beneath shining, minutely punctured and pubescent; last abdominal with apical depression, margin with three teeth, the two inner ones somewhat united.

Length 2.5 mm.; width 1.6 mm.

Female.—Last ventral obtusely rounded with a spine at apex.

Holotype male, allotype and paratypes collected from *Acalypha hederacea* Torr.[3] in Uvalde Co., Tex., June 26–27, 1940; paratypes from Val Verde Co., Tex., June 28, 1940, by D. J. and J. N. Knull. Type material in collection of writer, paratype in The Ohio State University collection.

---

[3] Determined by Dr. F. W. Pennell.

This species may readily be separated from any of our other forms by the placement of the elytral pubescence.

Euryptera texana n. sp.

Female.—Form elongate, black, with exception of head, thorax, scutellum, mesasternum, anterior and middle femora, which are yellow.

Head densely finely punctured, pubescence not conspicuous; antennae reaching beyond middle of elytra when laid along side of pronotum, scape stout, second joint as long as wide, third shorter than first, fourth shorter than third, fifth longer than third, following joints decreasing in length to eleventh which is longer than tenth; second, third and fourth joints slender.

Pronotum wider than long, much narrower at apex than at base, widest at base, sides broadly rounded in front, expanded toward base, hind angles acute; disk convex, with slight basal depression on each side, a transverse depression in front of scutellum; surface densely punctured, each puncture bearing a recumbent hair. Scutellum triangular, densely punctured and pubescent.

Elytra wider than base of pronotum, widest at humeral angles; sides nearly parallel, apices rounded, with obtuse angle at outer side of curve; disk convex; surface densely finely punctured, each puncture bearing a recumbent hair.

Abdomen beneath sparsely punctured in middle, punctures dense along sides.

Length 11.5 mm.; width 3 mm.

Described from one specimen collected in the Davis Mountains, Texas, July 3, 1940, by D. J. and J. N. Knull. Holotype in collection of writer.

Aside from color this species differs from *E. ignita* (Schffr.) by the more finely punctured pronotum. From *E. cruenta* Martin it differs by having larger punctures on elytra than pronotum.

Textbook of Zoology

The largest difference between this edition and the previous one is the addition of a chapter on ecology; the remainder of the book is essentially the same brought up-to-date. The new chapter is that sort of ecology which is largely a recitation and classification of relationships between animals and their environments. The factors operating to bring about these circumstances receive little attention. It would seem that selection of essential information from the chapters Interpreting Animals, Interpreting Plants, and Ecology, and its arrangement into an orderly system would have produced a section of greater merit. The tinted paper, new type, and colorful binding make a very attractive book.—*Carl Venard.*

Animal Biology, by Michael F. Guyer. xix + 723 pp. 423 figs. 3rd ed. New York, Harper and Brothers. 1941. $3.75.

HYDROGEN-ION CONCENTRATION AND THE INITIATION OF GROWTH

CYRIL J. CORUM
Western Reserve University

Experiments have been carried out in the past on the effect of hydrogen-ion concentration on the initiation of growth, using the spores of many fungi and the pollen grains of a few angiosperms. Likewise, work has been reported, using fungus spores, potato tuber tissue, fungus mycelium, root tips, and succulent cactus tissue, which indicates that the protoplasm of plant tissue behaves as though it were a protein with a definite isoelectric point. This behavior has been determined on the basis of water absorption, the behavior of the tissue in relation to staining with acid and basic dyes, and by the effect of the tissue upon the reaction of solutions in which it is immersed. The literature dealing with these points will be considered briefly in connection with the discussion of the results of the present experiments.

The experiments reported in this paper are concerned with the effect of hydrogen-ion concentration upon the germination of the spores of *Rhizopus suinus* Niels. and upon the sprouting of the tubers of the potato, *Solanum tuberosum* L.

EXPERIMENTAL

I. The influence of hydrogen-ion concentration upon the germination of the spores of *Rhizopus suinus* Niels.

The buffer solutions used for the germination tests were made up after the method of Webb (14). Phosphoric acid and potassium hydroxide were made up in m/5 concentrations, both solutions containing mannitol in a concentration of m/5. The two solutions were combined in various proportions to give a wide range of hydrogen-ion concentrations and were sterilized in the autoclave for 15 minutes at 15 pounds pressure.

The spore suspensions were prepared after the method of Tilford (11). Thirteen different buffer solutions, each with a volume of 15 cubic centimeters, were used to remove the spores from an equal number of agar slant cultures of the fungus. The hydrogen-ion concentrations of the solutions were redetermined after the spores were taken up in order to be sure that there was no change in pH as a result of absorption of materials from the agar slants. The values given in the tables for the hydrogen-ion concentrations of the different solutions are these redetermined values.

TABLE I

THE EFFECT OF HYDROGEN-ION CONCENTRATION ON THE GERMINATION OF THE SPORES OF *Rhizopus suinus*

Tube Number	pH	Percentage of Spore Germination
1	1.2	0.0
2	2.2	22.3
3	3.3	36.6
4	4.0	67.6
5	5.0	17.6
6	5.7	90.0
7	6.2	80.0
8	7.0	50.0
9	7.6	27.8
10	8.0	16.5
11	8.8	12.6
12	9.3	5.8
13	10.0	0.0

TABLE II

THE EFFECT OF HYDROGEN-ION CONCENTRATION ON THE GERMINATION OF THE SPORES OF *Rhizopus suinus*. SECOND SERIES.

Tube Number	pH	Percentage of Spore Germination
1	1.1	0.0
2	2.4	21.0
3	3.1	30.0
4	4.2	61.1
5	4.6	43.0
6	5.6	94.8
7	6.5	58.1
8	7.2	31.0
9	7.8	23.1
10	8.6	11.0
11	9.0	5.3
12	10.0	0.0

Hanging drop cultures were made from each tube. Evaporation from the drop was prevented by placing a small quantity of the non-inoculated buffer of the same pH in the bottom of the cell and by sealing the cover glass to the cell with vaseline.

After twenty-four hours the spore germination counts were made. Five fields were counted from each cell, and three cells were used for each pH value. In all, a total of about five hundred spores at each pH were counted, and the percentage of germination was calculated. The production of germ tubes was taken as the sole criterion of germination, those spores which merely showed swelling being disregarded. The results of the first series are contained in Table I.

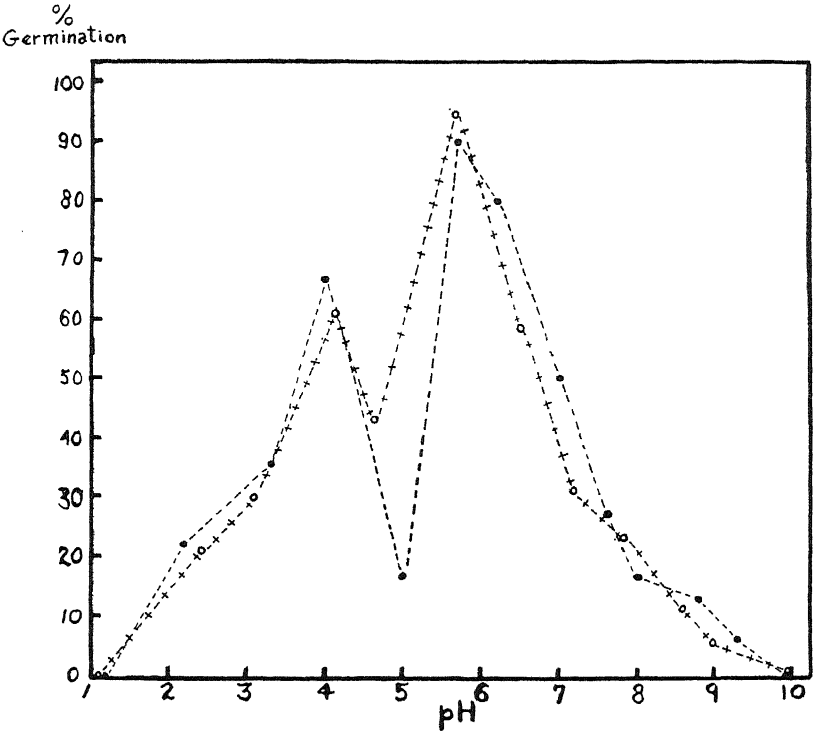


Figure 1. The effect of hydrogen-ion concentration upon the germination of the spores of *Rhizopus suinus*. Series one is represented by the broken line with closed circles; series two by the crossed line with open circles.

In a second series of experiments, which were carried out exactly as described above, except that the hydrogen-ion concentrations of the different solutions varied a little from the values used in the first series, very similar results were obtained. These results are given in Table II.

In figure 1 the percentage of spore germination is plotted against hydrogen-ion concentration expressed as pH. The results of both curves are used. Although the two curves are apparently somewhat different, it may be seen that it is possible to obtain from the two curves a single smoothed curve passing through the important points of both experimental curves.

II. The effect of hydrogen-ion concentration on the sprouting of tubers of *Solanum tuberosum* L.

The further influence of the concentration of hydrogen-ions on the initiation of growth was demonstrated through the use of potato tubers. The experiments were carried out in the late spring, in order to eliminate from consideration the factor of dormancy.

The buffers used in these experiments were prepared from an m/5 solution of monobasic potassium phosphate and an m/10 solution of citric acid. These solutions were mixed in varying proportions to give a series of fifteen buffer mixtures, ranging in hydrogen-ion concentration from that equal to pH 2.0 to that equal to pH 9.3.

TABLE III

THE EFFECT OF HYDROGEN-ION CONCENTRATION ON THE GERMINATION OF POTATO TUBERS

Container Number	pH	Average Sprout Length in mm.	
		Two Weeks	Three Weeks
1	2.0	0.0	0.0
2	2.3	0.0	0.0
3	2.5	0.0	0.0
4	3.0	0.0	0.0
5	3.5	0.0	0.0
6	4.0	0.0	0.0
7	4.5	13.0	17.0
8	5.0	8.0	12.0
9	5.5	8.0	24.0
10	6.1	7.0	25.0
11	6.5	9.0	15.0
12	7.0	4.0	10.0
13	7.9	9.0	13.0
14	8.5	10.5	24.0
15	9.3	8.0	14.0

Potato tubers of the Wisconsin Rural variety were cut in half, sterilized in a 0.1 per cent solution of bichloride of mercury, rinsed, and three half-tubers were immersed in each of the buffer solutions. After the twenty-four hour immersion period was completed, the tubers were removed from the buffers, resterilized in the bichloride solution, and air dried for 48 hours to promote suberization of the cut surfaces and thus to prevent rotting. These half-tubers were then placed in moist sphagnum in containers fashioned from two large pot-saucers. At the end of a two-week period, and again at the end of a three-week period, the sprouts which had developed were measured. Measurements of the apical sprouts were not taken, as these in general tend to be somewhat erratic in their behavior. The results, expressed as an average of the sprout lengths of the three half-tubers used at each hydrogen-ion concentration are given in Table III and are shown in figure 2. A second series gave similar results.

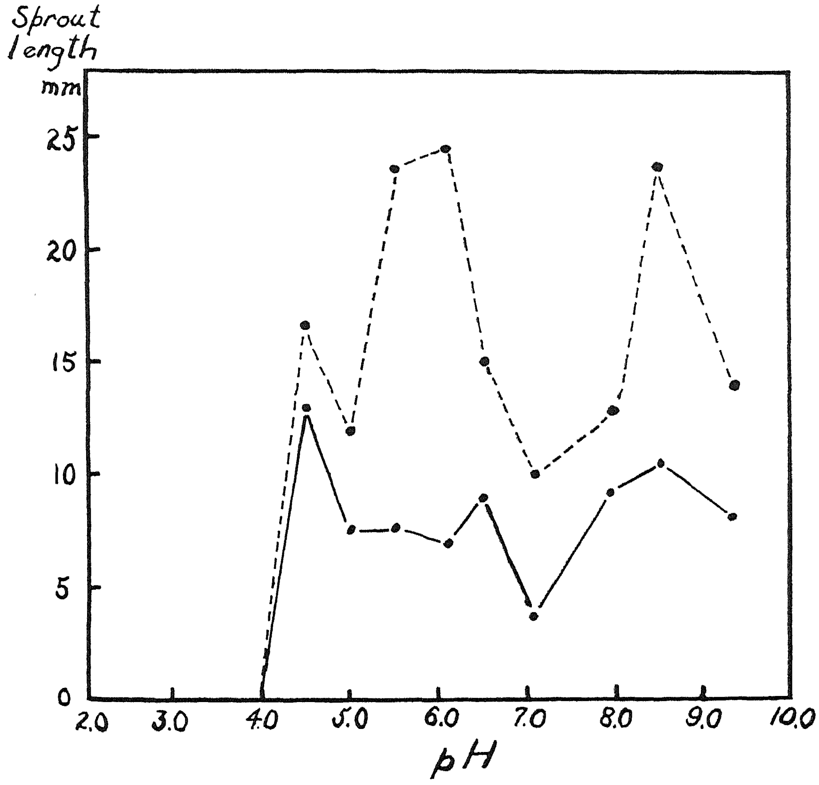


Figure 2. The effect of hydrogen-ion concentration on the sprouting of potato tubers. The solid line represents two weeks of growth; the broken line represents three weeks of growth.

DISCUSSION

There is established by the experimental work herein reported a curve for the germination of the spores of *Rhizopus suinus* as a function of hydrogen-ion concentration which is bimodal in nature. The two maxima come at about pH 4.0 and at about pH 5.7. The point at which minimum spore germination occurs lies between these, at about pH 5.0. This minimum point has been demonstrated by other authors. Robbins (5) showed by experiments on the absorption of acid and basic dyes that the mycelium of *Rhizopus nigricans* responded much like a protein with an isoelectric point between pH 4.8 and pH 5.1, while the mycelium of *Fusarium lycopersici* responded like a protein with an isoelectric point in the vicinity of pH 5.5. Robbins and Scott (7) determined, by means of the effect of the tissue on the reaction of solutions that the minimum point (isoelectric point) for *Fusarium oxysporum* was at pH 4.9–5.0 and that for *Gibberella saubinetii* was near pH 6.2. Scott (10) showed that *Fusarium lycopersici* exhibited a minimum in the spore germination curve at pH 5.2. Webb (13, 14) showed that there was a minimum in the spore germination curve of *Penicillium cyclopium* at pH 7.0, and a *Fusarium* sp. had a minimum point in the curve at pH 6.2. On the other hand, this same author found a minimum point in the curves for *Aspergillus niger*, *Botrytis cinerea*, *Lenzites saepiaria*, *Penicillium italicum* and *Puccinia graminis* only under certain temperature conditions. Webb was apparently the first to call attention to the phenomenon of the double maximum. Tilford (11) found that *Sclerotinia fructicola* gave a minimum of spore germination at pH 6.0, the two maxima being obtained at about pH 2.4 and about pH 6.6. Webb and Fellows (15) found a minimum in the growth curve for *Ophiobolus graminis* at pH 8.3, with maxima at pH 5.2 and pH 9.6. The criterion used for growth in this case was the diameter of colonies produced on corn meal agar. Scott (9) found for *Fusarium lycopersici* a minimum in the growth curve at pH 5.2, using as a criterion of growth the dry weight of mycelium produced by the fungus in 24 days. This minimum value is identical with that obtained (10) by spore germination tests.

The occurrence of the double maximum is not confined to fungus tissue. Pfeiffer (2) tried experiments on the effect of hydrogen-ion concentration on the germination of pollen grains. He found a minimum in the curve for the pollen of *Alopecurus pratensis* at pH 4.4, while for that of *Phaseolus multiflorus*, *Urtica dioica*, *Betula verrucosa*, and *Melandryum album* the minimum came at pH 5.2. Robbins (4) further showed that there was a minimum in the water absorption of potato tuber tissue at about pH 6.0. Robbins and Scott (7) showed an isoelectric point for soy bean root tips at pH 6.2–6.4. Ulehla (12) demonstrated that sections of the succulent tissues of *Opuntia* sp. behaved like an ampholyte with an equilibrium point in the neighborhood of pH 5.6. Salter and McIlvaine (8) found a minimum in the growth curve of wheat seedlings at pH 6.15. In the experimental work of this paper on the sprouting of potato tubers in relation to hydrogen-ion concentration, the minimum in the curve is found at pH 7.0, with the maxima at pH 6.3 and pH 8.5.

In all of these phenomena which are concerned with the initiation of growth, it is found that when the initiation of growth is considered as a function of the hydrogen-ion concentration of the medium surrounding the particular plant organ concerned, a bimodal curve is established. The exact location of the two maximum points and of the minimum point depends upon the nature of the organ concerned, the particular buffer system used, the nutrition of the growing parts, the method of determining the response to the various levels of hydrogen-ion concentrations, and finally, to the various environmental conditions under which the experiments are carried out. Of these, temperature is of special importance.

Growth, which in its initial stages at least involves merely an increase in size, is entirely dependent upon the uptake of water. Loeb (1) showed that the physical properties, such as viscosity, osmotic pressure, conductivity, and *total swelling* of such a protein as gelatin are at a minimum at the isoelectric point of pH 4.7. The point at which minimum swelling, and hence minimum growth, takes place in complicated materials such as plant tissues must be a resultant of the isoelectric points of the biocolloids of the protoplasm of the tissue. This conception is not new, having been advanced by Robbins (3, 6), Robbins and Scott (7), Scott (10), and Tilford (11).

From the experimental data reported in this paper, it is evident that the relative toxicity of the hydrogen- and hydroxyl-ion varies greatly with different tissues. In the case of the sprouting of the potato tubers, good growth took place from about pH 4.5 to pH 6.5 and from about pH 7.9 to pH 9.3, the upper limit of hydroxyl-ion concentration used. The minimum point in the curve (the isoelectric point) was determined to be at pH 7.0. On the other hand, with the spores of *Rhizopus suinus*, almost the entire curve lies below pH 7.0. Germination values above fifty per cent are obtained only between the narrow pH ranges of about pH 3.5 to pH 4.5 and about pH 5.5 to pH 7.0. The minimum point in the curve is located at pH 5.0, where the concentration of hydrogen-ions is one hundred times that at the minimum point for the potato sprouting.

SUMMARY

1. Data for the effect of hydrogen ion concentration on the initiation of growth are given for two different types of asexual reproductive units—mold spores and potato tubers.

2. For both types of organs investigated, a bimodal curve for the effect of hydrogen-ion concentration on the initiation of growth is obtained. For the spores of *Rhizopus suinus* the minimum in the curve is at about pH 5.0. For the sprouting of the potato tubers the minimum in the curve is at about pH 7.0.

3. Hydrogen-ions are relatively more toxic to potato tissue than to the spores of *Rhizopus suinus;* hydroxyl-ions are relatively more toxic to the spores of *Rhizopus suinus* than to the potato tissue.

4. The effect of the hydrogen-ion concentration on the initiation of growth is considered to be directly related to the effect of hydrogen-ion concentration upon the hydration of the biocolloids of the protoplasm of the plant tissues concerned.

LITERATURE CITED

(1) **Loeb, Jacques.** Proteins and the Theory of Colloidal Behavior. New York. 1924.

(2) **Pfeiffer, Hans.** Kleine Beiträge zur Bestimmung des IEP von Protoplasm. II. Keimungsversuche mit Pollen im Vergleich mit refraktrometrischen Messungen. Protoplasms 12: 268–278. 1931.

(3) **Robbins, W. J.** The Analogy between Plant Tissue and a Protein. Proc. Inter. Cong. Plant Sci. 2: 1125–1138. 1929.

(4) **Robbins, W. J.** An Isoelectric Point for Plant Tissue and its Significance. Amer. Journ. Botany 10: 412–439. 1923.

(5) **Robbins, W. J.** Isoelectric Points for the Mycelium of Fungi. Journ. Gen. Physiol. 6: 259–272. 1923.

(6) **Robbins, W. J.** The Isoelectric Point for Plant Tissue and its Importance in Absorption and Toxicity. Univ. Missouri Studies in Botany 1: 1–60. 1926.

(7) **Robbins, W. J.** and **Irl T. Scott.** Further Studies in Isoelectric Points for Plant Tissue. Journ. Agric. Res. 31: 385–399. 1925.

(8) **Salter, R. M.** and **T. C. McIlvaine.** Effect of the Reaction of the Solution on Germination of Seeds and Growth of Seedlings. Journ. Agric. Res. 19: 73–96. 1920.

(9) **Scott, Irl T.** Hydrogen-ion Equilibrium of Mycelial mats of *Fusarium Lycopersici* in Salt Solutions and its Relation to Growth and Toxicity. Amer. Journ. Botany 16: 631–643. 1929.

(10) **Scott, Irl T.** Some Protein Analogies of the Mycelium of *Fusarium Lycopersici.* Missouri Agric. Exper. Sta. Res. Bull. 92. 1926.

(11) **Tilford, P. E.** The Relation of Temperature to the Effect of Hydrogen- and Hydroxyl-ion concentration on *Sclerotinia Fructicola* and *Fomes annosus.* Spore Germination and Growth. Ohio Agric. Exper. Sta. Bull. 567. 1931.

(12) **Ulehla, V.** Die Regulation der Wasserstoffionenkonzentration durch Sukkulentengewebe. Ein Beitrage zur Frage des isolektrischen Punktes der Pflanzenzelle. Protoplasma 3: 469–506. 1928.

(13) **Webb, R. W.** Studies in the Physiology of the Fungi. X. Germination of the Spores of Certain Fungi in Relation to Hydrogen Ion Concentration. Annals. Missouri Botan. Gard. 6: 201–222. 1919.

(14) **Webb, R. W.** Studies in the Physiology of the Fungi. XV. Germination of the Spores of Certain Fungi in Relation to the Hydrogen Ion Concentration. Annals Missouri Botan. Gard. 8: 283–341. 1921.

(15) **Webb, R. W.** and **H. Fellows.** The Growth of *Ophiobolus graminis* in relation to Hydrogen Ion Concentration. Journ. Agric. Res. 33: 846–877. 1926.

THE OHIO JOURNAL OF SCIENCE

VOL. XLI NOVEMBER, 1941 No. 6

ANNUAL REPORT

OF THE

OHIO ACADEMY OF SCIENCE

1941

THE OHIO ACADEMY OF SCIENCE

Organized 1891 Incorporated 1892

Affiliated with the American Association for the Advancement of Science

---

OFFICERS AND COMMITTEES FOR 1941–1942

President

EUGENE VAN CLEEF

Vice-Presidents

A. *Zoology:* J. PAUL VISSCHER
B. *Botany:* CLARENCE E. TAFT
C. *Geology:* GEORGE B. BARBOUR
D. *Medical Sciences:* PAUL C. KITCHIN
E. *Psychology:* HAROLD EDGERTON
F. *Physics and Astronomy:* R. S. SHANKLAND
G. *Geography:* A. J. Wright
H. *Chemistry:* WILLIAM MANUEL
I. *Mathematics:* C. O. WILLIAMSON
J. *Junior Academy:* C. W. JARVIS

Secretary

ARTHUR W. LINDSEY

Treasurer

EDWARD S. THOMAS

Executive Committee

Ex-Officio: EUGENE VAN CLEEF, ARTHUR W. LINDSEY AND EDWARD S. THOMAS
Elective: WM. LLOYD EVANS, ROBT. M. GEIST

Trustees of Research Fund

CHARLES G. SHATZER, term expires	1942
PAUL B. SEARS, term expires	1943
HERBERT OSBORN, *Chairman*, term expires	1944

Library Committee

MRS. ETHEL M. MILLER, *Chairman*,
Librarian in charge of Academy Exchanges and Publications

JAMES R. PATRICK, term expires	1942
FRANCIS E. RAY, term expires	1943

Committee on Conservation

A. E. WALLER, *Chairman*, term expires	1942
EMERY R. HAYHURST, term expires	1942
L. E. HICKS, term expires	1942
DWIGHT M. DELONG, term expires	1943
T. H. LANGLOIS, term expires	1943
J. D. SAYRE, term expires	1943
G. W. CONREY, term expires	1944
PAUL B. SEARS, term expires	1944
E. L. WICKLIFF, term expires	1944

Committee on Nominations for 1942

THE VICE-PRESIDENTS OF 1940–1941

Membership Committee for 1942

A. *Zoology:* ROBERT M. GEIST
B. *Botany:* CONSTANTINE J. ALEXOPOULOS
C. *Geology:* PARIS B. STOCKDALE
D. *Medical Sciences:* FRANK E. HAMILTON
E. *Psychology:* L. D. HARTSON
F. *Physics and Astronomy:* R. L. EDWARDS
G. *Geography:* RODERICK PEATTIE
H. *Chemistry:* PAUL ROTHEMUND
I. *Mathematics:* O. L. DUSTHEIMER
J. *Junior Academy:* J. W. BRANSON

Academy Representatives

(1) On Joint Administrative Board, O. J. S.: JAMES R. PATRICK, term expires 1942, and FRANCIS E. RAY, term expires 1943.
(2) On Council of the A. A. A. S.: WILLIAM H. ALEXANDER.
(3) On Save Outdoor Ohio Council: ROSCOE W. FRANKS.

The Council for 1941–1942

ALEXANDER, WILLIAM H.
ALEXOPOULOS, CONSTANTINE J.
BARBOUR, GEORGE B.
BRANSON, J. W.
DUSTHEIMER, O. L.
EDGERTON, HAROLD
EDWARDS, R. L.
EVANS, WILLIAM LLOYD
GEIST, ROBERT M.
HAMILTON, FRANK
HARTSON, L. D.
JARVIS, C. W.
KITCHIN, PAUL C.
LINDSEY, A. W.
MANUEL, WILLIAM A.
OSBORN, HERBERT
PATRICK, JAMES R.
PEATTIE, RODERICK
RAY, FRANCIS E.
ROTHEMUND, PAUL
SHANKLAND, R. S.
STOCKDALE, PARIS B.
TAFT, CLARENCE E.
THOMAS, EDWARD S.
VAN CLEEF, EUGENE
VISSCHER, J. PAUL
WALLER, A. E.
WILLIAMS, STEPHEN R.
WILLIAMSON, C. O.
WRIGHT, A. J.

REPORT OF THE FIFTY-FIRST ANNUAL MEETING OF THE OHIO ACADEMY OF SCIENCE

The fifty-first meeting of the Academy was held in Cleveland on May 8, 9 and 10, 1941. The local committee, under the chairmanship of Dr. J. Paul Visscher, planned sectional meetings in the Wade Park Manor Hotel, as well as the meeting of the council and the general meeting and banquet. Although the space available for sectional meetings was hardly adequate, the convenience of meeting under one roof was noteworthy, since the weather proved to be cold and rainy. The innovation is to be recommended where adequate space can be secured.

The general scientific meeting on Thursday evening, May 8, was also offered by the committee as an innovation. Dr. George M. Curtis, speaking on *Jared Potter Kirtland, Pioneer Naturalist of the Western Reserve*, and Dr. M. L. Pool on *Artificial Radio Activity and Its Application to Industrial and Medical Research*, contributed a most interesting program.

The Academy owes the local committee its gratitude for the pleasant setting of the meeting and for the facilities provided, as well as for the resources of the city that were made available to us.

At the meeting following the annual banquet, Dr. J. Paul Visscher, acting as toastmaster, presented Dr. William E. Wickenden of Case School of Applied Science and Dr. Webster G. Simon of Western Reserve University who spoke briefly to the assembled members. President Stephen R. Williams then read his presidential address, *The Saga of Paddy's Run*, an unusual contribution to the annals of the Academy but an interesting one, nevertheless.

In the business meeting following the banquet, Dr. Grover presented changes in the constitution as passed by the Council. The most momentous change dealt with Article XI, Section e, to permit the reversal of Council action by a majority vote of the members voting instead of the three-fourths formerly required. Another change established standing committees on necrology and resolutions in place of the former temporary appointments. The last change provided four year terms for Academy representatives on the Administrative Board of the Ohio Journal of Science, one representative to be elected every two years. The Academy duly adopted these changes.

Membership in the Academy was increased by twenty-eight, and the following members were elected to fellowship:

John Warren Aldrich	Western Reserve University
Constantine John Alexopoulos	Kent State University
Bertil G. Anderson	Western Reserve University
Franklin James Bacon	Western Reserve University
Marion Waterman Boesel	Miami University
Benjamin P. Bole, Jr	Cleveland Museum of Natural History
Arthur M. Brant	Ohio State University
Robin Charles Burrell	Ohio State University
David Culbertson Chandler	Stone Laboratory of Ohio State University
Norman F. Childers	Ohio State University
Harla Ray Eggleston	Marietta College
George Marion Ehlers	University of Michigan
Morgan William Evans	Ohio Agricultural Experiment Station
Roscoe Whitlock Franks	Ohio State Civil Service Commission
William Franklin Hahnert	Ohio Wesleyan University
Augustus A. Hall	Ohio State University
Frank Errett Hamilton	Ohio State University
Arthur Roland Harper	Department of Education of Ohio, Columbus
Frank O. Hazard	Wilmington College
Edwin E. Heizer	University of Wisconsin
Freeman Smith Howlett	Ohio State University
Charles W. Jarvis	Ohio Wesleyan University
Clyde Harold Jones	Ohio State University
George Tallmon Jones	Oberlin College
James Bridges Lackey	U. S. Public Health Service, Cincinnati
Milan A. Logan	University of Cincinnati
Willard Machle	Kettering Laboratory, U. of Cincinnati
Francis John Molz	University of Dayton
George David Morgan	Denison University
David C. Rife	Ohio State University
Lee Stuart Roach	Ohio Division of Conservation of Natural Resources, Athens
Albert Ray Shadle	University of Buffalo
Ralph V. Sinnett	Ohio Wesleyan University
Archie Norman Solberg	University of Toledo
Waldo Edward Steidtmann	Bowling Green State University
Thomas C. Surrarrer	Baldwin-Wallace College
Aravilla Meek Taylor	Lake Erie College
Wilbur Metellus Tidd	Ohio State University
Walter Andrews Tucker	Columbus Dispatch
Carl Ernest Venard	Ohio State University
Charles Frederic Walker	Stone Laboratory of Ohio State University
John West Wells	Ohio State University
Arthur Baldwin Williams	Cleveland Museum of Natural History
Alfred J. Wright	Ohio State University

The list of officers preceding this report shows the results of the election excepting one item. In presenting the report of the nominating committee Dr. Price suggested the name of Mr. William H. Alexander as historical secretary. Since this office is new, amendment of the constitution is required to create it. At the suggestion of several speakers Mr. Alexander was asked to act as historian until appropriate action could be taken to create such an office.

At this point action was taken on the committee for the revision of the constitution. The Academy voted to continue the committee of the past year under the chairmanship of Dr. Grover.

Dr. John G. Albright presented the report of the committee on Necrology and Dr. Edward W. E. Schear that of the Committee on Resolutions.

The meeting adjourned after brief discussion of several items of business of a less formal nature.

In presenting this brief report the secretary wishes to explain the delay in its presentation. The officers of several sections were not reported in the spring. Repeated inquiry failed to secure some of the names and in other cases no election had been held. At last, with the generous aid of President Van Cleef, the list was completed after the middle of September. Other peculiarities of the report must be laid to the fact that a change in secretaries itself causes some confusion.

Respectfully submitted,
A. W. Lindsey, *Secretary.*

Report of the Treasurer

Columbus, Ohio, May 9, 1941.

To the Ohio Academy of Science:

I submit herewith a financial statement of the condition of the Ohio Academy of Science as of December 31, 1940. The books have been audited and the opinion of the auditor is herewith attached.

Respectfully submitted,
Edward S. Thomas, *Treasurer.*

Balance Sheet as at December 31, 1940

Assets

Current Expense Fund:		
Cash in Bank—Current		$ 222.25
Cash in Bank—Semi-Centennial Celebration		607.40
Total Cash—Current Expense Fund (Schedule 1)		$ 829.65
Dues Receivable:		
1938	$ 10.00	
1939	60.00	
1940	362.50	
Total Dues Receivable		432.50
Interest Receivable (Bond coupons not cashed in 1940)		39.00
Bonds—Consolidated Federal Farm Loan 3 per cent 1945–55		1,300.00
Total Assets—Current Expense Fund		$2,601.15

RESEARCH FUND:		
Cash in Bank	$ 87.16	
Banc-Ohio Securities Company Stock (cost)	437.50	
Bonds—Fort Hayes Hotel, Columbus, Ohio (cost)	1,300.00	
Total Assets—Research Fund		1,824.66
Total Assets		$4,425.81

Liabilities, Deferred Credits and Net Worth

LIABILITIES:		
Accounts Payable		$ 260.61
DEFERRED CREDITS TO INCOME:		
Reserve for Uncollected Dues 1938, 1939 and 1940	$ 432.50	
1941 Dues Collected in 1940	20.00	
Total Deferred Credits to Income		452.50
Total Liabilities and Deferred Credits to Income		$ 713.11
NET WORTH:		
Ohio Academy of Science:		
Current Expense Fund Surplus	$1,378.25	
Semi-Centennial Celebration Surplus	509.79	
Research Fund Surplus	1,824.66	
Total Net Worth (Schedule 2)		3,712.70
Total Liabilities, Deferred Credits and Net Worth		$4,425.81

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS FOR THE YEAR ENDING DECEMBER 31, 1940

CASH BALANCE—DECEMBER 31, 1939:			
Ohio Academy of Science—Current Fund			$ 27.37
Semi-Centennial Celebration			100.00
Total Cash Balance—December 31, 1939 (as per books)			$ 127.37
DEPOSITS FOR THE YEAR:			
Ohio Academy of Science Receipts:			
Cash Received in 1939, Deposited in 1940		$ 2.50	
Dues 1940		1,197.40	
Dues 1939		55.00	
Dues 1938		22.50	
Dues 1941		20.00	
Research Grants		150.00	
Federal Farm Loan Coupons		19.50	
Sale of Publications		3.00	
Miscellaneous Income		1.00	
Total Deposits—Ohio Academy of Science		$1,470.90	
Semi-Centennial Celebration:			
Cash Received in 1939 Deposited 1940	$150.00		
Receipts for 1940	796.80		
Total Deposits—Semi-Centennial Celebration		946.80	
Total Deposits for the Year			2,417.70
Total Balance and Receipts			$2,545.07

DISBURSEMENTS (Checks Written):			
Ohio Academy of Science:			
Clerical Assistance		$ 11.60	
Postage and Telegraph		69.70	
Office Supplies and Expense		15.45	
Expenses of Officers to Meetings		72.17	
Printing:			
Proceedings of Ohio Journal of Science	$ 65.00		
Other	35.67		
		100.67	
Subscriptions to Ohio Journal of Science		675.00	
Research Grants		150.00	
Secretary's Honorarium		100.00	
Safety Deposit Box		3.30	
Bond for Treasurer		5.00	
Auditing Expense		15.00	
Bank Charges		5.13	
Reported Proceedings Annual Meeting		27.00	
Miscellaneous Expense		26.00	
Total Disbursements—Ohio Academy of Science		$1,276.02	
Semi-Centennial Celebration and Junior Academy:			
Stationery and Office Supplies	$ 25.35		
Postage	38.62		
Committee Expenses	147.78		
Printing	18.25		
Honorariums to Speakers	150.00		
Speakers' Traveling Expenses	46.90		
Publicity	12.50		
Total Disbursements—Semi-Centennial Celebration and Junior Academy		439.40	
Total Disbursements			1,715.42
CASH BALANCE—December 31, 1940			$ 829.65
Distributed as follows:			
Ohio Academy of Science			$ 222.25
Semi-Centennial Celebration			607.40
Total			$ 829.65

NET CASH BALANCE AFTER CONSIDERING OBLIGATIONS AS AT DECEMBER 31, 1940

	Cash	*Accounts Payable*	*Net*
Ohio Academy of Science	$222.25	$163.00	$ 59.25
Semi-Centennial Celebration	607.40	97.61	509.79
Totals	$829.65	$260.61	$569.04

COLUMBUS, OHIO, July 8, 1941.

The Ohio Academy of Science, Columbus, Ohio.

GENTLEMEN:—In accordance with your instructions, I have audited the accounts and records of the Treasurer of the Ohio Academy of Science for the year ended December 31, 1940.

All cash receipts and disbursements of the current expense fund were checked in detail for the period under review.

Cash in the bank was verified by bank confirmation and reconcilement with the book balance.

Investment securities on hand December 31, 1940, in the current expense fund, were examined and found to be as stated in the accompanying balance sheet. Cash and investment securities of the research fund were not verified in the course of this examination.

Members' dues accounts were not verified by correspondence with the members.

I hereby certify that, in my opinion, the accompanying Balance Sheet as at December 31, 1940, and related statement of Income and Expense fairly present the financial condition of the Ohio Academy of Science and the results of operation for the year ended that date.

Respectfully yours,
DANIEL M. SHONTING,
Certified Public Accountant.

Report of Trustees of the Research Fund

The accounts of the Research Fund for the year 1940 and submitted for audit as of December 31, 1940, were as follows:

CREDITS	
Balance January 1, 1940	$ 193.93
Deposits during 1940	74.00
Total Credits	$ 267.93
DEBITS	
Paid on Grants for Research from Research Fund	$ 178.91
Service Charges at Bank	1.86
Total Debits	$ 180.77
Balance in checking account January 1, 1941	$ 87.16
The Invested Funds are the same as a year ago:	
Bonds (at cost)	$1,300.00
Stocks Ohio National Bank (at cost)	437.50
Total	$1,737.50
Cash Balance in Checking Account	87.16
Total Assets	$1,824.66

The allotment from the A. A. A. S. for research projects for 1940, cleared through Treasurer's office, was assigned to Dr. Archie N. Solberg, Toledo Univ., $50.00, and Dr. J. W. Frink, Univ. of Cincinnati, $100.00, for projects approved by the Trustees and acceptable to the A. A. A. S.

Later additions and anticipated income for the current year will give us a free balance of over $150.00 and applications for grants during the current year will be welcomed.

The grant from the A. A. A. S. for research was increased to $175.00 for the present year and this will permit a larger allowance for research projects in progress. Since the allowance from the A. A. A. S. is likely to continue it would seem that we may anticipate grants of at least $200.00 each year. It is expected that all of the allowance from the A. A. A. S. will be expended during each year.

Respectfully submitted,
HERBERT OSBORN, *Chairman*,
C. G. SHATZER,
PAUL B. SEARS.

Report of the Joint Administrative Board of the Ohio Journal of Science

COLUMBUS, OHIO, April 26, 1941.

To the Ohio Academy of Science:

The only meeting of the Joint Administrative Board of the *Ohio Journal of Science* since the last report was held at the Ohio State University, April 26, 1941. Present were Messrs. Patrick, Lindsey, Transeau, Blake, Snyder, Meyer, Blaydes, and Miller. The meeting was called to order about 12:30 P. M., Dr. Patrick acting as chairman. The minutes of the preceding meeting were read and approved.

Dr. L. H. Snyder was elected Editor, Dr. G. W. Blaydes, Associate Editor, and Dr. John A. Miller, Business Manager of the *Journal* for the coming year. Dr. Blaydes had been serving as Associate Editor since last November when he was elected to that position by a mail ballot of the Board. Dr. Snyder's resignation, effective at the end of the coming year, was accepted with regrets. Dr. Meyer had advised the Board at its last meeting that he would not accept re-election as Business Manager for another year.

The Business Manager presented his report for the fiscal year 1939, as follows:

RECEIPTS

Balance from 1939	$ 35.98
University Allowance	750.00
Ohio Academy of Science—pro rata of dues	821.00
Subscriptions	125.06
Author's payments for plates	114.17
Sale of back numbers	19.89
Cleveland Clinic—Publication costs	160.00
Total	$2,026.10

EXPENDITURES

Spahr & Glenn Printing Vol. 40	$1,593.80
Bucher Engraving Company	195.80
Postmaster	122.00
Envelopes and stationery	36.90
Clerical assistance	7.50
Subscription refund	1.67
Bank charges	1.07
Total	$1,958.74
Balance on hand March 13, 1941 (Huntington National Bank)	67.36
	$2,026.10

Upon motion the report was accepted and placed on file. An auditing committee consisting of Dr. Transeau and Dr. Blaydes, found the report to be correct.

The Business Manager advised the Board of his action in deferring the mailing of foreign exchanges during present war conditions.

There was some informal discussion regarding the problems involved in publishing the 50th Anniversary number of the *Journal* and regarding the organization of the Board, but no formal actions were taken.

The meeting adjourned at about 2:00 P. M.

Respectfully submitted,
B. S. MEYER, *Secretary of the Board.*

Report of the Library Committee

COLUMBUS, OHIO, May 9, 1941.

To the Council of the Ohio Academy of Science:

The library committee has had no conferences and no correspondence this year.

The sales of publications amounted to $10.05. This sum plus six cents sales tax has been given to the Treasurer. A few Annual Reports were sold and ten Special Papers, half of which were Dr. W. G. Stover's Agaricaceae of Ohio. An order for a dozen copies of this paper has been received this year from Ohio University. This will appear in next year's report and will likely lead the list again in number of copies sold.

Last summer the mailing room at the Ohio State University obtained a new addressograph machine and made entirely new sets of stencils for the thirty or forty thousand names in its files including the members of the Ohio Academy of Science. The type is much larger and more easily read than were the former addresses. The new set of Academy cards was checked with the old set and a number of errors were found and corrected.

Several new exchanges have been added to the list. We now have 110 in this country and 272 abroad. Some of the foreign exchanges have come regularly during the past year, others intermittently and of course some not at all. More have come in the last few weeks than for several months. The first number of a new geography periodical in Spain was received recently with a request for exchange. No issues of our own *Ohio Journal of Science* have been sent this year to any place outside the Western Hemisphere. In January the Business Manager sent postal cards to the exchanges stating that all issues would be held here until a later time unless the recipient wished them sent at his own risk. So far no replies have been received.

The memorial volume in honor of the fiftieth anniversary of the founding of the Academy was the most important undertaking of the past year. Some of the members thought that it would be very appropriate to publish the pictures of the men and women who organized it and the chairman of this committee was asked to get them. Securing these pictures was a large and interesting piece of work and the history of it constitutes a large part of this report. The size of the task can be imagined when one considers that I had a list of fifty-nine names with their addresses of fifty years ago. I knew that six were still living and that several had relatives in Columbus. Dr. Herbert Osborn and Dr. William L. Evans were very helpful in giving suggestions about possible sources. However there were no clues whatever for twenty-four names.

The next question to be settled was how to get the pictures copied when they should come. I asked Dr. Raymond C. Osburn if the photographer in the Zoology Department of the Ohio State University might be permitted to do the work. He agreed readily, stating that he thought that his department could well make that contribution to the Ohio Academy of Science.

Having thus disposed of the preface I was ready for the first chapter in the story of the pictures. I started with the most probable ones. When asking for the loan of a picture I always stated that it would be copied by the photographer in our building and would be returned promptly. The response was most gratifying. Everyone seemed much pleased that the pictures were to be published, many expressed a desire for a copy of the volume, and some said that they wished to purchase one or more copies. When the pictures were returned to the owners a small print was always enclosed, which seemed to be appreciated by the recipient. Much credit is due to the photographer, Mr. Louis Waszy, for his prompt and efficient work in making the negatives and prints.

After writing for all the probable ones I started on those for which I had no clues and it was very interesting to see how clues were found in the most unexpected places. There is an interesting story connected with nearly every picture. I usually began with the public library of the town where the person had lived in 1890 or at a later date if I could learn such. And without exception the librarians were most accommodating and helpful. Many pictures could not have been secured if they had not given the assistance which they did, for they either obtained the actual pictures and sent them to me or else they furnished good clues as to where I might succeed in locating them. They are Miss Gertrude Robertson of the Cleveland Public Library, Mr. W. J. Hamilton, Dayton; Mrs. Viola C. Marlatt, Defiance; Miss Florence L. Irwin, Geneva; Miss Jennie A. Shuman, Kent; Mrs. Ruth H. Pierce, Painesville; Mrs. F. W. Moulton, Portsmouth; and Miss Mary McCann of the Sandusky Public Library; Miss Eleanor S. Wilby of the Historical and Philosophical Society of Ohio, and Mrs. Corinne M. Simons of the Lloyd Library, both at Cincinnati. Also the same assistance was given by college librarians, Mr. Deckard Ritter of Ohio Wesleyan; Mr. R. E. Stauffer of Mt. Union; and Miss Marguerite Mitchell of Wilmington; by Dr. Byron H. Nellans, Dean of the Eclectic Medical College at Cincinnati; by various professors at Akron, Heidelberg, Mt. Union, Miami, Oberlin, Ohio University, Ohio Wesleyan, and Ohio State; by Mr. James D. Hartshorne of the Cleveland *Plain Dealer;* by Mr. C. W. Parrott, Vice-President of The Lowe Brothers Paint Company at Dayton; and by the Good Samaritan Hospital at Zanesville. All of these deserve much credit for the interest they took and the efforts which they made.

As a last resort I took the Columbus telephone directory and phoned to the people with the same name, asking if they were by any chance related to the person in question. Two pictures were secured in this way.

The Secretary of the Academy had offered to write to the six living members: Mr. J. N. Bradford of Columbus, Dr. E. G. Conklin of Princeton, Dr. C. B. Morrey and Dr. George W. Twiss of Florida, Professor E. L. Moseley of Bowling Green, and Dr. A. L. Treadwell of Vassar College. During my search for pictures I learned of three more: L. M. Bloomfield, a former professor at Ohio State University, who lives near Lancaster; G. P. Grimsley, who recently retired from many years' service in the offices of the Baltimore and Ohio Railroad at Baltimore; and H. A. Surface, former State Zoologist of Pennsylvania, who lives or winters in Florida. (I have just learned during September that Mr. Lucius A. Hine is living in Highland Park, Illinois.) Thus ten of the fifty-nine original charter members are still living.

I succeeded in obtaining fifty-six of the fifty-nine pictures. One seems to be wholly non-existent, that of Mr. L. W. Gunckel of Dayton, and so far I have failed to get one of Mr. Frank J. Combs of Columbus, and of Professor Ellen E. Smith of Lake Erie College, Painesville, who was one of the two vice-presidents when the Academy was organized and who died a year or so later, in 1893 or 1894. Pictures came from twenty places in Ohio, as follows, twenty-one from Columbus, three each from Cincinnati and Cleveland, two from Delaware, and one each from Adams Mills, Akron, Alliance, Bowling Green, Chillicothe, Cuyahoga Falls, Dayton, Geneva, Granville, Lancaster, Oberlin, Oxford, Painesville, Sandusky, Tiffin, and Wilmington. Four came from Florida, from Ft. Myers, South Miami, Vero Beach, and Zephyrhills, and one each from Baltimore, Chevy Chase, Chicago, Minneapolis, Philadelphia, Poughkeepsie, and Washington, D. C. They were secured directly from the living members, and from the widows, sons, daughters, granddaughter, sisters, nieces, cousins, and brother-in-law of the other members, from college collections of pictures, and from books, for in a few cases no separate picture could be located.

From one to eleven letters were required for each picture. The eleven were in regard to Miss Jane F. Winn, a vice-president in 1895. Her case seemed almost hopeless but finally the picture came very unexpectedly from a friend of hers in Chicago, with an interesting sketch of her life. Quite a number of biographies were sent with the various pictures to be kept in the files of the Academy, if not published.

The results to date show that one hundred and forty-nine letters and twenty postal cards were written, numerous telephone calls were made, and sixteen trips were taken in Columbus to get and to return pictures. These figures do not include the number of letters which were written by the Secretary to the living members. The postage on the letters, cards, and parcels of pictures amounted to six dollars which was paid by the Ohio State University Library. Four of the pictures had to be purchased as they were available only at photographic studios. The prices were fifty cents, one dollar and two dollars each but as I was able to sell the last one for a dollar the total cost to the Academy for the four pictures was $4.50. So the actual cash outlay has been $10.50. In addition the Zoology Department of the Ohio State University furnished all the material for the negatives and prints, as well as the time of its photographer.

The entire project has taken much work and time. From September 26, 1940, when the first letters were written until January 7, 1941, when the last borrowed pictures were returned, the search for them consumed practically my entire time. Nearly everything else was either laid aside or handed over to my assistant. However, everyone co-operated so well and seemed so pleased that the pictures were wanted and were to be published in permanent form that it really was a very interesting task. There was always great satisfaction when a picture was received.

And now comes the next chapter in the story of these pictures. After securing them on the basis that they were to be published, the statement was made to me that there were no funds with which to do it, that there would be no memorial volume but that only the invitational addresses would be published in the May issue of the *Ohio Journal of Science.* I was much dismayed for I feel that we are under a moral obligation to all these people who sent pictures so willingly and gladly on the basis of their publication. They would make not more than seven plates and the cost would be between six and eight dollars a plate on the basis of a thousand copies. They could very well accompany the address on the history of the Ohio Academy of Science which was given by Dr. J. P. Porter last year. It would seem that the fiftieth anniversary should not be passed without the recording of its history in printed form.

Thus the final chapter to the story of the pictures has not yet been written. What it will be depends upon the action of the Academy. If it can find it possible to supply the fifty or sixty dollars necessary to publish them our obligation to the owners of these pictures can be fulfilled and the Academy will have a permanent record of its fifty-year history and of the men and women who organized it. On the other hand if the Academy be unable to see its way to appropriating this sum I shall be obliged to write about fifty more letters, stating that I regret it exceedingly but that it has not been found possible to publish them. Shall the story of the pictures have this kind of an ending as its last chapter or can we keep the pledges made to the owners of the pictures and thus give a happy ending to the story? May the Council decide.

Respectfully submitted,

ETHEL MELSHEIMER MILLER, *Chairman.*

EDITOR'S NOTE: The pictures of which Mrs. Miller speaks were published in the July, 1941 issue of the Ohio Journal of Science.

Report of Committee on Resolutions

Resolutions of this, the fifty-first meeting of the Ohio Academy of Science and fourth Cleveland meeting:

The Committee on Resolutions recommends that we express our appreciation for the very cordial reception we have received from our distinguished hosts, Western Reserve University and the Case School of Applied Science.

The precision with which the plans were formulated and have been and are being carried through are distinctly noteworthy and the fine spirit of co-operation on the part of the Wade Park Manor and the Convention Bureau of the Cleveland Chamber of Commerce is deserving special recognition.

The cultural atmosphere, the cordial co-operation on the part of the museums, the work of the entertainment committee in providing for the excursions and other features have made this meeting one long to be remembered by both members and guests.

Respectfully submitted,
RALPH V. BANGHAM,
H. RAY EGGLESTON,
EDWARD W. E. SCHEAR, *Chairman.*

Report of the Committee on Necrology

CLEVELAND, OHIO, May 9, 1941.

To the Ohio Academy of Science:

Notice of the death of four members of the Academy has come to the attention of your committee. The names are those of Dr. Maynard M. Metcalf, Dr. B. C. Freeman, Dr. Dayton C. Miller, and Dr. Francis H. Herrick. A short account of the life and work of each man follows:

MAYNARD M. METCALF

Dr. Metcalf was the retired Research Professor of Zoology of the Johns Hopkins University. He was born in Elyria, Ohio, in 1868, the son of Elijah Wright Metcalf and Maria Ely Metcalf. He was educated at Oberlin College and Johns Hopkins University, receiving the Ph. D. degree from the latter institution in 1893. He was Chairman of the Biology Department of Goucher College until 1906, when he became head of the Zoology Department of Oberlin College. In 1914 Dr. Metcalf resigned from college work to devote his time to research in the field. He worked both in this country and abroad. In 1924 he was Chairman of the Division of Biology and Agriculture of the National Research Council.

Dr. Metcalf was a member of the Ohio Academy of Science, and was its President in 1919. He had been a Trustee from 1913 to 1917. His published works numbered more than 150, dealing mostly with evolution, sociology, economics and philosophy. He died in Winter Park, Florida, April 22, 1940.

BRUCE CLARK FREEMAN

Dr. Freeman was a member of the Geology Department at the Ohio State University. He died August 25, 1940, in his sleep, while on a geological field trip for the Quebec Bureau of Mines. He was about 40 years of age.

DAYTON C. MILLER

Dr. Dayton C. Miller, distinguished scientist and teacher, died at his home in Cleveland on February 22, 1941. He was born in Strongsville, Ohio, on March 13, 1866. He received the B. S. and M. S. degrees from Baldwin-Wallace College, and the Doctorate of Science from Princeton University (1890). His first position was as instructor of mathematics and physics at the Case School of Applied Science, and he remained on the faculty for fifty years, rising through the rank of assistant professor to the head professorship of physics. He retired from active duty in June, 1940. He was responsible for the plans and construction of the Rockefeller Laboratory of Physics at Case. His chief work was done in the field of acoustics. He invented the phonodeik, which made visible the complex wave-forms of sound waves, and amplified them several thousand times. His consultation was frequently asked in the improvement of the acoustical qualities of large auditoriums. Among his notable researches were those concerning the tone qualities of musical instruments. He was a lover of music, and composed about thirty pieces of music for the piano, the flute and other musical instruments. Among his works are eight published books.

He was a member of the National Academy of Sciences as well as many other scientific organizations. He received at various times five honorary doctor's degrees. He was an inspiring teacher and a most productive research worker.

FRANCIS HOBART HERRICK

Dr. Herrick was born in Woodstock, Vermont, on November 19, 1858. He died in Cleveland on September 11, 1940. He received his formal education at St. Paul's School, Concord, N. H., graduated from Dartmouth College in 1881, and received the Ph. D. degree from Johns Hopkins University in 1888. He was Professor of Biology at Western Reserve University from 1888 until he became Professor Emeritus in 1929. He was known throughout the world for his work on the embryology and life history of Crustacea, especially the lobster. Outstanding was his definitive biography of the famous naturalist John James Audubon. In later years he conducted his well-known ornithological studies on the American Eagle.

Respectfully submitted,
JOHN G. ALBRIGHT, *Chairman.*

AUTHORS' ABSTRACTS AND BRIEF ARTICLES

A. THE SECTION OF ZOOLOGY

Courses of the Bald Faced Hornet (Dolichovespula Maculata)—By KELLEY HALE, Wilmington, Ohio.

In July, 1940, Nathan Hale discovered a queen's nest in the early stage of construction attached to the underside of the terra cotta above the entrance to Hale Surgical Hospital.

Daily photographs with 35 mm. Kodachrome were made through a 135 mm. telephoto lens mounted on a miniature camera until activity of the colony ceased in November, 1940.

It was soon discovered that the workers were using similar courses, some being quite complex due to large trees and buildings. Fourteen courses had been established and maintained throughout the season.

I quote from a letter received from Dr. Carl D. Duncan of San Jose State College, author of a fine book on the Vespena:

"On various occasions I have noted that wasps follow fairly definite courses in leaving and returning to their nests. However I do not know of anyone who has carefully observed such behavior for any length of time and published the results of his observations. It may be therefore, that you have collected data that are worthy of publication."

Suggested plan for solution of course problem of bald faced hornet:

1. Note carefully the courses followed by the queen during construction of the queen's nest.

2. Observe if the subsequent courses of the workers coincide or not with those of the queen. I am anxious to hear from as many observers as possible on this particular point.

3. I am desirous to know if each worker follows a particular course or is shifted from one course to another. To solve this point we could do the following experiments:

(a) Mark all the workers on a particular course dusting or spraying to see if they change courses.

(b) Net all the workers of a certain course and keep them in captivity long enough to see if others take their place. When released they should be marked for identification.

(c) Kill all the workers of a course with mustard shot.

(d) Kidnap the workers of a particular course and at a distance turn them loose at different times and points of the compass (after marking) and see how many return and by which routes.

(e) See if a hornet can return to the nest from a nearby point in its course after painting its eyes with an opaque substance.

(f) Disorient the nest if attached to a twig that can be removed.

4. If the queen does not lay out the courses perhaps the first brood does; if so, how do the subsequent or future workers learn the course or courses so well?

Since no published observations have been made on identical courses of Bald Faced hornets so far as I can learn, I am offering this paper hoping to stimulate further work and experiments on this most intriguing subject.

I learned that it is a common belief that hornet nests are used more than one season. With rare exceptions this is not true.

B. THE SECTION OF BOTANY

Are the Green Algae Ancestral to the Embryophyta:—By GEORGE T. JONES, Oberlin College, Oberlin, Ohio.

Three primary objections to the theory that land plants arose from the Chlorophyceae are presented: (1) the ecological objection that a small green thallus adjusted to aquatic life would not be likely to survive if stranded on an unshaded beach; (2) it is contrary to all other experience that a complete parasite, such as the Riccia sporophyte, should develop autonomy; and (3) the necessary assumption that Riccia is primitive is not justified by the evidence of sequence of forms within the class Hepaticae itself. An alternative theory is proposed that the Embryophyta is more closely related to the Phaeophyceae than to any other group of living algae. Similarity of general form, identical modes of increase in size, ability to withstand drying, the occurrence of sieve tubes in both, multilocular gametangia, alternation of unequal generations, and the possibility of migration to terrestrial habitats through brackish marshes are cited as arguments in favor of the latter theory. The Pteridophytes and Phaeophyceae would both arise from a common stock, having alternation of equal generations, the former becoming terrestrial and the latter remaining marine. The Bryophyta would diverge from the most primitive Pteridophytes through reductive adaptation to an understory habit.

Water-Loss in Relation to Leaf Structure in American Holly, Tobacco, and Coleus:—By C. A. SWANSON, Ohio State University, Columbus, Ohio.

Simultaneous determinations of the rate of water-loss in potted plants of *Ilex opaca*, *Nicotiana sp.*, and *Coleus blumeii* were made under the same environmental conditions. Despite the very thick cuticle and other "xeromorphic" peculiarities of holly leaves, the rate of transpiration per sq. dm. of lower leaf surface in this species was generally higher than in the other two species.

Growth Habits of Reed Canary Grass:—By MORGAN W. EVANS and J. ELBERT ELY (deceased), Ohio Agricultural Experiment Station, Wooster, Ohio.

The underground rooting stems or rhizomes of reed canary grass (*Phalaris arundinacea* L.) originate chiefly during May, June, July, and August. Above-ground shoots develop in largest numbers during fall and early spring. In the latitude of northern Ohio, culms, with their elongated internodes, begin to form about or soon after the middle of April. The proportion of shoots producing inflorescences increases with improved cultural conditions. Shoots which begin their growth in the spring and summer are not winter hardy, and their life is limited to the same season. The life of a shoot which develops in the fall is limited to the growing season of the following year.

In the latitude of northern Ohio, inflorescences begin to develop from the growing points of the shoots about or very soon after the middle of April; flowering begins in early June; seeds mature in late June and early July. Flowering and maturing gradually progress from just below the tip of the inflorescence toward its base. The leaves of reed canary grass are destroyed by temperatures not low enough to destroy the leaves of timothy, redtop, or Kentucky bluegrass.

The American Species of Micrasterias:—By R. K. SALISBURY, Greenhills, Cincinnati.

The author has found twenty-two species, thirteen varieties, two forms of Micrasterias in Florida. Krieger (1939) has listed fifty-six (56) species and one hundred thirty-six (136) varieties for the world, of which thirty-three (33) species and thirty-seven (37) varieties are given for the United States.

Forms of *M. radiata* not heretofore published and a new variety of *M. sol* were shown.

M. radiata is very variable and appears to show characteristics of other species with which it is found. The validity of certain varieties established on the basis of spines is questioned.

Morphological Variations of Rhizopus Suinus Niels. Under Various Physiological Conditions:—By C. J. CORUM, Western Reserve University, Cleveland, Ohio.

Continued sub-culture of *Rhizopus suinus* for a period of thirty months upon a synthetic nutrient agar medium resulted in gradual diminution in ability of the organism to produce spores. Finally a stage was reached in which there was no sporulation whatever, the mycelial mat produced being a pure white color.

In the weakly-sporing cultures several types of abnormalities were observed, viz.: peculiar bulbous hyphal enlargements, highly branched sporangiophores, great variations in size of sporangia and spores, and incomplete cleavage in some sporangia—all indications of an abnormal condition of the cultures. Other abnormal growths found in the sterile cultures were an extensive irregular branching of the hyphae, and an abundant occurrence of chlamydospores from which short germ tubes were frequently seen to protrude.

Restoration of the spore-forming ability of the cultures could be accomplished by growing the fungus on potato dextrose agar or on a synthetic agar to which thiamin had been added. The cultures could be returned rather rapidly to the non-sporulating condition by growing the fungus on a synthetic medium, using as a carbon source dextrose that had been extracted with acetone, alcohol, and ether to remove the thiamin.

The Forest Situation in Ohio:—By OLIVER D. DILLER, Ohio Agricultural Experiment Station, Wooster, Ohio.

Ohio has two distinct forest problems. In the hilly, southeastern, one-third where the timber tracts are relatively large, there are vast areas of worn out land where fire, overcutting, and soil erosion have depleted the soil, and lowered the standard of living. The greatest rural relief load is here.

In the level two-thirds the woodlands are in small, scattered patches, which total three and a quarter million acres, give the highest quality timber, and in spite of neglect produce an annual income of about four million dollars, or slightly over one dollar an acre. This is only about one tenth of the income that could be obtained under proper handling.

The problems of re-establishing forest cover by forest planting, and of properly protecting and managing the existing woodlands to produce a sustained yield of the higher grade timbers were discussed and illustrated. The need of adequate appropriations from the state legislature for carrying out a long time forest program was emphasized.

C. THE SECTION OF GEOLOGY

The Fauna and Stratigraphic Relationships of the Prout Limestone and Plum Brook Shale of Northern Ohio:—By ERWIN C. STUMM, Department of Geology, Oberlin College, Oberlin, Ohio.

The Prout limestone with its predominant coral and brachiopod fauna is correlated with the Centerfield limestone of the New York Hamilton. The guide fossils of this horizon with special mention of the brachiopods "*Spirifer*" *venustus*, *Camarophoria kernahani*, *Eunella attenuata*, and *Pentagonia bicostata*, are discussed. The underlying Plum Brook shale is correlated with the Skaneateles. The fossils of both formations are illustrated on five plates.

*Pseudo-Algal Nodules in the Greenfield Dolomite (Silurian of Ohio).*By JOHN W. WELLS, Department of Geology, Ohio State University, Columbus, Ohio.

The nodules found in the Greenfield dolomite at its type locality near Greenfield, Ohio, show no trace of structures attributable either directly or indirectly to algae and they are thought to be the result of physico-chemical deposition.

Stylolites—Primary or Secondary?—By PARIS B. STOCKDALE, Department of Geology, Ohio State University, Columbus, Ohio.

After surviving nearly two decades of general acceptance by American geologists, the solution theory for the origin of stylolites is being further studied in light of the substitute "contraction-pressure" theory recently proposed by B. M. Shaub. According to the new theory stylolites are a *primary* structure which originated while sediments were in the unconsolidated state from differential pressure and contraction which compelled "transfer of material by plastic flow." The solution theory holds that stylolites are a *secondary* phenomenon developed after consolidation and hardening of strata through rock removal by differential chemical solution. The preponderance of field evidence along many lines shows that stylolite-making has involved removal of rock material after lithification of the sediments. A recently discovered occurrence of large and well-defined stylolites in sharply laminated limestone gives no evidence of readjustment or reshaping of sediments through differential squeezing or flow. The stylolites are of secondary origin and give further support to the solution theory.

The Relation of Geology and Physiographic History to Floods in the Muskingum Valley:—By H. ANDREW IRELAND, Soil Conservation Service, New Philadelphia, Ohio.

The Muskingum valley has a complex physiographic history brought about by several cycles of preglacial erosion, Pleistocene erosion, and glaciation. Quantitative evidence is given to show that soils, outwash gravel, and the more gentle slopes of glaciated areas allow absorption of a large amount of precipitation and large ground water storage results. The ground water is fed into the streams maintaining a large flow even during dry seasons. The gravel fill in the entrenched valleys of the Deep Stage has much more storage space than similar valleys filled with slack-water silt. Depletion curves, run-off graphs, and measurement of ground water accretion to stream flow are used as evidence of differential absorption. Differences are explained on the basis of geologic and physiographic conditions. The effect of drainage patterns inherited from preglacial systems and drainage changes due to glaciation are interpreted in regard to their effect on floods.

Relation of Soil-Creep to Earthflow in Eastern Ohio:—By C. F. STEWART SHARPE and EARL F. DOSCH, U. S. Soil Conservation Service, New Philadelphia, Ohio.

Recent studies of soil movements on agricultural lands in parts of the Appalachian Plateau underlain by Pennsylvanian and Permian rocks containing numerous coals, clays, and shales reveal that the widespread slow process of soil-creep prepares the way for the localized and much faster earthflow.

On a typical hill slope in this area only the most massive beds of rock are exposed; the position of the weaker beds is obscured by a mantle of soil and rock debris. Road cuts and deep auger borings show that horizontal beds of coal, clay, and shale, instead of outcropping, thin abruptly and bend down slope several feet below the surface and may be traced down the hillside in attenuated form for as much as 200 feet. A clay or shale layer thus drawn out parallel to the slope interferes with downward percolation of surface water and of ground water that has moved laterally outward above the undisturbed clay stratum.

During and following heavy precipitation the more or less impervious blanket of creeping clay locally brings about saturation of overlying material, and, on moderate or steep slopes with insufficient vegetal cover to retain the soil, an earthflow may result.

Down-stream Narrowing of the Valley Floors of Lower Cuyahoga and Rocky Rivers:—By HENRY F. DONNER, Western Reserve University, Cleveland, Ohio.

In the lower six or eight miles of their courses, Cuyahoga River has cut into unconsolidated, glacial material whereas Rocky River has cut almost entirely into bedrock. For the last two and one-half miles both rivers seem to be in an earlier stage of physiographic development than they are farther up-stream. Difference in material along the valley is a minor cause, except in Rocky River where the valley cuts across the filled-in, preglacial channel. Evidence indicates that Big Creek may have entered Cuyahoga River some two miles farther down stream at an earlier stage. Both streams widened their valleys along their parallel courses until the divide separating them was removed. This, in part, may explain the wide portion of Cuyahoga Valley extending from Big Creek to a point about two miles north.

A general cause, affecting both rivers, was the repeated changing of the lake level. At any particular lake stage the stream entering it developed a somewhat winding course. As the lake dropped to a new level the old, winding course persisted but the portion connecting the old shore line with the new took a more direct course. Lateral cutting was greater in the winding parts than in the straight ones; hence these upper valleys were widened more rapidly than the lower ones.

An Unusual Landslide:*—By ROBERT H. MITCHELL, Muskingum College, New Concord, Ohio.

An unusual type of mass-movement occurred in a road cut near Zanesville, Ohio. In this slide the movement was largely horizontal, producing a "pseudo-graben" at the head of the slip. This condition is of interest since only normal slipping occurred on the opposite side of the road-cut under apparently similar conditions. Since the factors which favor mass-movement were present on both sides of the road-cut the different effects noted on opposite sides of the road must be due to varying combinations of the governing factors.

---

*This article will appear soon in the Journal of Geology.

A PRELIMINARY SURVEY OF MEXICAN PSYLLIDAE (HOMOPTERA)

JOHN S. CALDWELL,
Circleville, Ohio

The psyllid fauna of Mexico has scarcely been touched and doubtlessly extensive collecting will recover many species recorded from America North of Mexico and from countries farther south along with species new to science. The data to substantiate this statement is contained in the few papers concerning Mexican Psyllidae and the fact that floral type scarcely conforms to international boundaries. The probable occurrence of species new to Mexico makes a key to the present species valueless; however, it appears that the majority of likely genera are represented and a tentative key is presented. The following compilation is based on data published by D. L. Crawford, F. Laing, H. G. Ferris, and E. P. Van Duzee, and the collections of D. M. DeLong and the writer's.

TENTATIVE KEY TO GENERA

1. Frons visible as a distinct sclerite; head never deeply cleft in front; genae not produced into cones........................2.
   Frons usually covered by genae; or if visible, head is deeply cleft in front; genae usually produced into cones.............5.
2. Frons visible from below as an elongate sclerite; vertex more or less flattened...3.
   Frons visible from front as a rounded sclerite bearing the anterior ocellus; vertex rounded more or less downward in front. 4.
3. Forewings hyaline, ovate, sometimes maculate; no pterostigma present. Proctiger of male with posterior lobes.......**Aphalara**
   Forewings opaque, thickened, rhombodial; pterostigma present. Proctiger of male without caudal lobes.........**Aphalarioda**
4. Vertex, frons, and genae continuing in a uniform surface; antennae not longer than length of head and thorax combined. **Paurocephala**
   Vertex, frons, and genae not a uniform surface, genae slightly swollen on either side of frons; antennae very long. .**Heteropsylla**
5. Head very deeply cleft in front with antennae arising at base on either side accentuating the bifed appearance; frons sometimes visible..6.
   Head not deeply cleft in front; frons never visible.............9.

6. Forewings with cubital petiole..............................7.
Forewings without cubital petiole..............................8.

7. Forewings with pterostigma and pseudocrossveins connecting radius and medius..............................**Carsidara**
Forewings with pterostigma but no pseudocrossveins between radius and medius..............................**Freysuila**
Forewings with neither pterostigma nor crossveins.......**Epiciasa**

8. Posterior tibiae with never more than four apical spines; medius of forewings two branched......................**Rhinopsylla**
Posterior tibiae with at least five apical spines; medius of forewings appearing three branched....................**Synoza**

9. Forewings without a definite cubital petiole (*Ceropsylla* has either a tendency toward a petiole or a very short indefinite petiole); basal tarsus of hind legs without two black claws....10.
Forewings with a very definite cubital petiole; two black spines present of basal tarsus of hind legs......................15.

10. Genae produced into cones..............................11.
Genae not produced into cones....................**Kuwayama**

11. Forewings with a very short cubital petiole or tendency toward such; radius usually darkened....................**Ceropsylla**
Forewings with absolutely no cubital petiole................12.

12. Pronotum long, flat; forewings long, slender; genal cones projecting rather forward..............................**Leuronota**
Pronotum short, descending; forewings various, usually broad; genal cones descending..............................13.

13. Genal cones short; clypeus visible from front..........**Paratrioza**
Genal cones longer; clypeus not visible from front.............14.

14. Metacoxae without anterior spurs......................**Trioza**
Metacoxae with anterior spurs.................**Phylloplecta**

15. Thorax strongly arched; forewings somewhat rhombodial; species mostly robust..............................16.
Thorax not strongly arched; forewings ovaloid; species not especially robust..............................17.

16. Head and thorax perpendicular, pubescent, forewings hyaline with costa pubescent..........................**Spanioneura**
Head and thorax not perpendicular, not pubescent; forewings usually subhyaline..............................**Euphalerus**

17. No line of demarkation between vertex and genal cones; epimeron and episternum of prothorax subequal in length. **Psyllopsis**
Genal cones and vertex not fused; epimeron shorter than episternum..............................18.

18. Genal cones usually separated at bases; vertex with a whitish ridge along either side of median line............**Mitropsylla**
Genal cones contiguous at base; vertex without marked ridges along median line..............................**Psylla**

RECORD OF SPECIES

Genus **Aphalara** Forster

Aphalara nupera Van Duzee. Angeles Bay, 5-4-21, and Gongales Bay, 4-29-21, Lower California, (E. P. Van Duzee & J. C. Chamberlin). The elongate clypeus places this species in the *calthae* group.

Aphalara simila Caldwell. Mexico City-Toluca road km. 20, 11-24-38, (Caldwell). Tamazunchale, San Luis Potosi, 8-29-39, (D. M. & F. M. DeLong). Jiutepec, Morelos, 9-6-39, (DeLong & C. C. Plummer).

Aphalara veaziei metzaria Crawford. San Esteban Island, Lower California, 4-19-21, (Van Duzee & Chamberlin).

Aphalara numerica n. sp. Monterrey, Nuevo Leon, 11-1-38, (Caldwell).

Aphalara caudata Crawford. Mexico City, D. F., west 18 kms., 9-1-39, (DeLong & Plummer).

Aphalara punctellus Van Duzee. San Nicolas Bay, Lower California, 5-16-21, (Van Duzee & Chamberlin). The nine segmented antennae places this species in the subgenus *Anomocera*.

Genus **Aphalaroida** Crawford

Aphalaroida inermis Crawford. Santa Engracia, Tamaulipas, 11-8-38, (Caldwell).

Genus **Paurocephala** Crawford

Paurocephala magnifrons Crawford. Escuintla, Chiapas, 7-25-10, (Crawford).

Paurocephala (*Aphalara*) *mera* (Van Duzee). San Nicolas Bay, Lower California, 5-16-21, (Van Duzee & Chamberlin). This species was described as an *Aphalara* with a pterostigma. Its placement here is arbitrary as it is possible it may belong in *Metaphalara* Crawford* along with *M. ilicis* (Ashmead).

Genus **Heteropsylla** Crawford

Heteropsylla mexicana Crawford. Jalapa, Vera Cruz, 8-28-10, (Crawford). Tamazunchale, San Luis Potosi, 11-15-38, (Caldwell).

Heteropsylla forcipata Crawford. Oaxaca, Oaxaca, (A. Koebele), Tamazunchale, San Luis Potosi, 8-29-39, (DeLong). Jiutepec, Morelos, 9-6-39, (DeLong & Plummer).

Heteropsylla mimosae Crawford. Santa Engracia, Tamaulipas, 11-4-38 and 11-8-38, (Caldwell).

Heteropsylla hausachae n. sp. Santa Engracia, Tamaulipas, 11-4-38, 11-8-38, and 11-11-38; Acapulco, Guerrero, 11-22-38; Valles, San Luis Potosi, 12-1-38, (Caldwell).

---

* D. L. Crawford: Broteria Serie Zoologica, vol. 22, fasc. 11, p. 60, 1925.

Genus **Carsidara** Walker

Carsidara gigantea Crawford. Mexico City, D. F., (H. H. Smith). Manazanillo, Colima; Petatlan, Guerrero; near mouth of Balasa River, Guerrero; Minatitlan, Vera Cruz, (G. F. Ferris). Iguala, Guerrero, 9-11-38, (DeLong).

Carsidara dugesii Loew. "Mexico," (A. Duges). Acapulco, Guerrero, (DeLong).

Carsidara mexicana Crawford. Acapulco, Guerrero, (C. F. Baker).

Genus **Freysuila** Aleman

Freysuila dugesii Aleman. Guanajuata, Guanajuata, (A. Duges).

Freysuila coahuayanae Ferris. Colima & Coahuayana, Colima, (Ferris).

Genus **Epicrasa** Crawford

Epicrasa corniculata Crawford. Petatlan, Guerrero, near mouth of Balsas River, Guerrero, (Ferris).

Genus **Rhinopsylla** Riley

Rhinopsylla jalapensis Crawford. Jalapa, Vera Cruz, 8-28-10, (Crawford).

Rhinopsylla nigra Laing. Orizaba, Vera Cruz, (F. D. Godman and H. H. Smith). Mexico City, D. F., west 18 Kms., 9-1-39, (DeLong).

Rhinopsylla elongagena n. sp. Mexico City-Toluca road km. 20, 11-24-38, (Caldwell).

Rhinopsylla rubrafacia n. sp. Cuernavaca, Morelos, 9-8-39, (DeLong & Plummer).

Genus **Synoza** Enderlein

Synoza pulchra Laing. Chilpancingo, Guerrero, (Smith). Colima, Colima, December, 1925, (Ferris).

Genus **Kuwayama** Crawford

Kuwayama medicaginis Crawford. Jalapa, Vera Cruz, (Crawford). Santa Engracia, Tamaulipas, 11-4-38, (Caldwell). Iguala, Guerrero, 9-11-39, (DeLong).

Kuwayama oaxacensis Crawford. Oaxaca, Oaxaca, (Crawford). Mexico City-Toluca road km. 20, 11-24-38, (Caldwell). Mexico City, D. F., 9-1-39, (DeLong).

Genus **Leuronata** Crawford

Leuronata mihoacana Ferris. Chinicuila, Michoacan, February, 1926, (Ferris).

Leuronata maculata (Crawford). Sihuatenejo, Guerrero, 2-19-26, (Ferris).

Genus **Paratrioza** Crawford

Paratrioza cockerelli Sulc. Santa Engracia, Tamaulipas, 11-5-38, (Caldwell). Mexico City, D. F., 9-13-39, (DeLong).

Genus **Ceropsylla** Crawford

Ceropsylla sideroxyli Riley. Zacutula, near mouth of Balasa River, Guerrero, (Ferris).

Ceropsylla johnsonii Crawford. Valles, San Luis Potosi, 12–1–38, (Caldwell).

Genus **Trioza** Forster

Trioza mexicana Crawford. Cuernavaca, Morelos, (Crawford).

Trioza mexicana minuta Crawford. Oaxaca, Oaxaca, (Crawford). Mexico City, D. F., 9–1–39 and 9–13–39, (DeLong & Plummer).

Trioza proximata Crawford. Oaxaca, Oaxaca, and Orizaba, Vera Cruz, August, 1910, (Crawford). Mexico City-Toluca road km. 20, 11–24–38, and Mexico City-Acapulco road km. 55, 11–23–38, (Caldwell). Mexico City, D. F., 9–1–39 and 9–13–39, (DeLong & Plummer).

Trioza longistylus Crawford. Mexico City, D. F., 9–13–39, (DeLong & Plummer).

Trioza arizonae Aulmann. Tamazunchale, San Luis Potosi, 8–29–39, (DeLong).

Trioza thoracia n. sp. Mexico City-Toluca road km. 20, 11–24–38, (Caldwell).

Trioza koebelei Kirkaldy. Cuernavaca Morelos, (A. L. Herrera). Santa Engracia, Tamaulipas, 11–4–38, (Caldwell).

Genus **Phylloplecta** Riley

Phylloplecta diospyri (Ashmead). La Providencia near Acapulco, Guerrero, (Ferris).

Genus **Spanioneura** Forster

Spanioneura arcuata (Crawford). Jalapa, Vera Cruz, 8–28–10, (Crawford). It may be of interest to note here that this species was taken on Bonefish Key, Florida, 2–22–40, (Caldwell)

Genus **Euphalerus** Schwarz

Euphalerus fasciatus Laing, Atoyac, Vera Cruz, (Smith).

Euphalerus gallicola Ferris. Near mouth of Balasa River, Guerrero, (Ferris).

Genus **Psyllopsis** Crawford

Psyllopsis mexicana Crawford. Acapulco, Guerrero, (Baker).

Genus **Mitrapsylla** Crawford

Mitrapsylla albalineata Crawford. Acapulco, Guerrero, (Baker). Oaxaca, Oaxaca, (Crawford).

Genus **Psylla** Geoffory

Psylla orizabensis Crawford. Orizaba, Vera Cruz, 8–28–10, (Crawford). Cuernavaca, Morelos, 9-8-39, (DeLong & Plummer).

Psylla nana Tuthill. Mexico City, D. F., west 18 kms., 9–1–39, (DeLong).

Aphalara numerica n. sp.

Length to tip of forewing, male 2.2 mm., female 2.5 mm.; forewing, male 1.6 mm., female 2 mm.

General color greenish yellow with small dark brown maculae on forewings. Scutum with the figure "1001" appearing in white with the ones short and broad, and the zeros not quite closed caudad.

Antennae slightly longer than width of head. Vertex deeply notched in front; foveae very deep; ocelli prominent. Cubital cell in forewings long, narrow; medial cell small.

Forceps of male short, clavate apically; inner apical tooth reaching to apex of forcep proper.

Female genitalia as long as rest of abdomen in dried specimens. Dorsum of dorsal valve gently sinuate.

Male holotype, female allotype, and paratypes from Monterrey, Nuevo Leon, 11–1–38, (Caldwell).

Heteropsylla huasachae n. sp.

Length to tip of forewing, male 2 mm., female 2.2 mm.; forewing, male 1.5 mm., female 1.7 mm.

General color yellow to yellow-orange; eyes and apex of antennae black; forewings sometimes milky.

Antennae about twice as long as width of head. Head as broad as thorax. Forewings subhyaline; pterostigma broad, short, almost touching the radial sector.

Proctiger of male suddenly narrowed in apical third. Forceps appearing hemipyriform with truncate apices in lateral aspect; in caudal view the inner lobes are visible and appear to be of same shape as outer lobes though slightly shorter.

Dorsal valve of female about one-half as long as rest of abdomen; dorsum sulcate. Ventral valve about one-half as long as dorsal.

Male holotype, female allotype, and paratypes from Santa Engracia, Tamaulipas, 11–4–38; paratypes from same locality on 11–8–38 and 11–11–38, also paratypes from Acapulco, Guerrero, 11–22–38, and Valles, San Luis Potosi, 12–1–38, (Caldwell).

Trioza thoracia n. sp.

Length to tip of forewing 3.2 mm., forewing 2.8 mm.

General color light brown with legs and venter lighter; three apical segments of antennae black.

Antennae one-fourth longer than width of head. Vertex twice as broad as long; lateral and basal margins raised; apical margin deeply notched. Genal cones short, appressed, almost at right angles to plane of vertex; apices sharp. Prothorax almost perpendicular. Forewings about two and a half times as long as broad; rather rounded apically. Metacoxae with posterior spurs; hind tibiae with apical spine ratio of 3–1.

Forceps of male extremely long, slender, slightly curved cephalad; apices with a single black tooth projecting inward.

Male holotype from Mexico City-Toluca road km. 20, 11–24–38, (Caldwell).

Rhinopsylla elongagena n. sp.

Length to tip of forewing 3 mm., forewing 2.6 mm.

General color grey-yellow; vertex with narrow median stripe, meso- and metathorax with three and five red stripes respectively.

Anterior ocellus barely visible from above. Sulcate impressions on vertex almost obsolete. Genae greatly swollen, resembling rather blunt cones, yet clypeus is visible from front. Veins of forewings golden, three marginal spots deep black.

Dorsal valve of female greatly lowered in caudal third to styliform slightly upturned apex. Ventral valve with short styliform apex.

Female holotype Mexico City-Toluca road km. 20, 11-24-38, (Caldwell).

Rhinopsylla rubrafacia n. sp.

Length to tip of forewing 4 mm., forewing 3 mm.

General color of head and thorax light brown, abdomen black; basal antennal segments bright red; a white waxy secretion down median of abdominal dorsum.

Foveae in vertex very deep. Anterior ocellus not visible from above. Thorax scarcely arched; legs rather short. Forewings about three times as long as broad; apices not acute; three marginal spots scarcely visible.

Female genital segment short; ventral valve scarcely longer than preceding segment; dorsal valve short, thick, arched.

Female holotype from Cuernavaca, Morelos, 9-8-39, (DeLong & Plummer).

BIBLIOGRAPHY

Crawford, D. L. 1914. A Monograph of the Jumping Plant-Lice of the New World. U. S. National Museum Bull. 85.

Ferris, G. F. 1928. Observations on Chermidae (Hemiptera: Homoptera). Canadian Entomologist 60, pp. 109-117 and 240-245.

Laing, Frederic. 1923. On Some Psyllidae (Hem.-Hom.) from the New World. Annals & Magazine of Natural History (9) 11: 696-705.

Van Duzee, E. P. 1923. Expedition of the California Academy of Sciences to the Gulf of California in 1921. (The Hemiptera) Proceedings of the California Academy of Sciences 12: 199-200.

Aquatic Animals Have Osmotic Troubles

This systematic survey of the osmotic adjustments made by aquatic animals and the mechanisms which aid in these adjustments is most thorough in every respect. The phyla of the animal kingdom are treated separately. The sixteenth chapter considers eggs and embryos. Notes on methods are included. The list of references extends to nearly 280 titles which brings the literature up to the date of publication.

For one who is dealing with aquatic forms this book is obviously indispensable.—*W. M. Barrows.*

Osmotic Regulation in Aquatic Animals, by August Krogh. ix+242 pp. 54 figures and tables. London, Cambridge at the University Press, 1939. $3.75.

STUDIES IN ANTIBIOSIS BETWEEN BACTERIA AND FUNGI.

II. Species of Actinomyces Inhibiting the Growth of Colletotrichum gloeosporioides Penz. in Culture

CONST. J. ALEXOPOULOS
Phytopathological Laboratories,
Institut de Chimie et d'Agriculture "Nicolaos Canellopoulos"
Piraeus, Greece

Department of Biology, Kent State University

In the first paper of this series[1] the writer and his associates reported that *Actinomyces albus* Krainsky was found to inhibit the growth of all ten of the species of fungi against which it was tested in culture. The inhibitory effects were shown to be due to some chemical substance toxic to the fungi which the inhibiting organism probably manufactured in the medium. It was stated there, that during the past two years the writer "has observed that the colonies of organisms belonging to this genus (Actinomyces), occurring as contaminations in Petri dishes in the routine laboratory work with fungi, frequently inhibited the growth of many fungi." These observations led to experiments with a large number of species of Actinomyces in order to determine how universally such toxic substances are produced by members of this genus.

The fungus employed in these experiments was a monoconidial isolation of *Colletotrichum gloeosporioides* Penz. isolated from diseased twigs of *Citrus sinensis* Osb. from Gargalianoi, Greece. This was grown together with 80 different Actinomycetes obtained from the Centraalbureau voor Schimmelcultures, Baarn, Holland, as follows:

A. albidoflavus (R. D.) Gasp.
A. albidus Duché.
A. alboflavus W. et C.
A. albosporeus Krainsky.
A. albus (R. D.) Gasp.
A. albus (R. D.) Gasp. var. *alpha* Cif.
A. albus (R. D.) Gasp. var. *cretaceous* (Krüger) Wr.
A. albus (R. D.) Gasp. var. *ochroleucus* (Neuk.) Wr.
A. almquisti Duché
A. annulatus Beij.
A. asteroides (Ep.) Gasp.
A. aureus W. et C.
A. baarnensis Duché.
A. bobili W. et C.
A. bovis Harz.

---

[1] Ohio Jr. Sci., 38: 221-235, 1938.

A. buccalis (Wins.) West.
A. cacaoi Waks.
A. californicus W. et C.
A. canis (R. D.) West.
A. caprae (Sil.) Lieske.
A. carnosus Mill. et Burr.
A. cellulosae Krainsky.
A. chromogenus Gasp.
A. citreus Gasp.
A. clavifer Mill. et Burr.
A. craterifer Mill et Burr.
A. dassonvillei (B. R.) West.
A. deri (R. D.) West.
A. diastaticus Krainsky.
A. epidermidis (Rosenb.) West.
A. farcinicus (De T. et Trev.) West.
A. fimicarius Duché.
A. flavogriseus Duché.
A. flavovirens Waks.
A. flavus Krainsky.
A. flavus Mill. et Burr.
A. fradii W. et C.
A. gougeroti Duché.
A. griseus Krainsky.
A. halstedii W. et C.
A. heimi Duché.
A. intermedius Wr.
A. keratolytica Act. et McG.
A. krainskii Duché.
A. langeroni Salvanet-Duval.
A. lipmanii W. et C.
A. luteus (Ch. et Ar.) West.
A. maculatus Mill. et Burr.
A. madurae (Vinc.) Lehm. et Neum.
A. microflavus Krainsky.
A. nigrificans (Krüger) Wr.
A. odorifer (Rull.) Lieske.
A. oligocarbophilus Beij.
A. olivaceus Waks.
A. orangicus (R. D.) West.
A. pelletieri (Lav.) West.
A. pheochromogenus Conn.
A. praecox Mill. et Burr.
A. purpeochromogenus W. et C.
A. reticuli W. et C.
A. roseodiastaticus Duché.
A. roseus Krainsky.
A. ruber Krainsky.
A. rutgersensis W. et C.
A. salmonicolor Mill. et Burr.
A. sampsonii Mill. et Burr.
A. sanfelicei (Red.) West.
A. sanninii (Cif.) West.
A. scabies (Thaxt.) Güssow.
A. setonii Mill. et Burr.
A. sulphureus Gasp.
A. tenuis A. Cast.
A. tumuli Mill. et Beeley.
A. tyrosinaticus Krainsky.
A. verne W. et C.
A. violaceus-caesari W. et C.
A. violaceus-ruber W. et C.
A. viridis Mill. et Burr.
A. viridochromogenus Krainsky.
A. xanthostroma Wr.

No attempt was made to verify the identity of the various species, the names used being those supplied with the cultures by the Centraalbureau voor Schimmelcultures. All specific names regardless of their derivation are spelled in lower case letters.

Each species of Actinomyces was grown together with *Colletotrichum gloeosporioides* in the same Petri dish. The fungous inoculum was placed in the center of the Petri dish while the Actinomyces was inoculated two centimeters away from the center on opposite sides. The fungus was inoculated five days after the Actinomyces so as to give the latter an opportunity to become well established. The fungus was inoculated by means of a small loopful of a water suspension of conidia. The Actinomyces was inoculated by using a small loopful of a heavy, water suspension of the organism and dividing it between the two points of inoculation in the same Petri dish.

The medium employed was prepared according to the following formula:

Maltose	30.00	gr.
$MgSO_4$	.50	gr.
K_2HPO_4	1.00	gr.
KCl	.50	gr.
$FeSO_4$	.016	gr.
$NaNO_3$	2.00	gr.
Agar	20.00	gr.
Water	1000.00	cc.

Sufficient N/1 NaOH was added to the medium so that after sterilization the pH was approximately 7.4 .15 cc. of agar were used to the Petri dish. All tests were carried out in triplicate. Ten Petri dishes inoculated with the fungus alone served as controls. Observations on growth were made at intervals of 24 hours, and the inhibitory distances[2] recorded as in previous experiments.

According to the results obtained in these experiments, the 80 forms of Actinomyces studied can be classified into three groups with reference to their effect upon the growth of *C. gloeosporioides* in culture, as follows:

1. *Strong inhibitors.* Forms which inhibited the growth of the fungus at an inhibitory distance of 10 or more millimeters.
2. *Weak inhibitors.* Forms which inhibited the growth of the fungus at an inhibitory distance of less than 10 mm.
3. *Non-inhibitors.* Forms which had no effect upon the growth of the fungus.

The Actinomycetes are classified accordingly in Table I. It will be seen from this table that 45 (56.25%) of the cultures of Actinomyces tested, inhibited the growth of *C. gloeosporioides* while 35 (43.75%) had no effect upon the growth of the fungus. Of the inhibiting organisms 14 (31%) were strong inhibitors while 31 (69%) were weak inhibitors.

It now seemed advisable to test the ability of filtrates from liquid cultures of a few species of Actinomyces belonging to each of the above three groups, to retard the growth of the fungus. Accordingly, a liquid medium of the following formula was prepared:

Glucose	30.0	gr.
Peptone	5.0	gr.
KH_2PO_4	1.0	gr.
Water	1000.0	cc.

Sufficient NaOH was added to impart a pH 7.4 to the sterilized medium. No effort was made, however, to regulate the pH very accurately because previous experiments had shown that even rather large variations in pH did not seem to have an effect on inhibitory phenomena. 20 cc. of the medium were used to each 200 cc. flask.

From each Actinomycete group, three species were selected for this experiment. From the strong inhibitors, *A. ruber*, *A. flavus* Kr. and

---

[2] Ibid, p. 223.

A. oligocarbophilus were used; from the weak inhibitors, *A. bobili*, *A. flavovirens*, and *A. chromogenus*, while from the non-inhibitors, *A. albosporeus*, *A. sulphureus*, and *A. canis* were selected.

Three flasks of medium were inoculated for each of the above species. Four flasks were also inoculated with *C. gloeosporioides*, and four others were left uninoculated to serve as controls. Sixteen days after inoculation, the organisms were filtered off by means of filter paper and the filtrates were used in preparing nutrient agar which after sterilization at 15 lbs. pressure for 15 minutes, was poured into Petri dishes and inoculated with a loopful of a spore suspension of *C. gloeosporioides*. Measurements of the largest and smallest diameter of each colony were made and recorded for seven days. The results are summarized in

TABLE I

ACTINOMYCES SPECIES CLASSIFIED ACCORDING TO THEIR ABILITY TO INHIBIT THE GROWTH OF *Colletotrichum gloeosporioides* IN CULTURE ON MALTOSE AGAR

Strong Inhibitors	Weak Inhibitors	Non-inhibitors
A. albidoflavus	*A. albidus*	*A. albosporeus*
A. alboflavus	*A. albus* var. *alpha*	*A. albus* (R. D.) Gasp.
A. annulatus	*A. albus* var. *cretaceous*	*A. almquisti*
A. clavifer	*A. albus* var. *ochroleucus*	*A. asteroides*
A. farcinicus	*A. aureus*	*A. baarnensis*
A. flavus Kr.	*A. bobili*	*A. canis*
A. flavus Mill. et Burr.	*A. buccalis*	*A. carnosus*
A. krainskii	*A. bovis*	*A. epidermidis*
A. madurae	*A. cacaoi*	*A. fimicarius*
A. microflavus	*A. californicus*	*A. fradii*
A. oligocarbophilus	*A. caprae*	*A. griseus*
A. ruber	*A. cellulosae*	*A. halstedii*
A. sanninii	*A. chromogenus*	*A. heimi*
A. scabies	*A. citreus*	*A. keratolytica*
	A. craterifer	*A. luteus*
	A. dassonvillei	*A. nigrificans*
	A. deri	*A. olivaceus*
	A. diastaticus	*A. orangicus*
	A. flavogriseus	*A. pelletieri*
	A. flavovirens	*A. phaeochromogenus*
	A. gougeroti	*A. roseodiastaticus*
	A. intermedius	*A. roseus*
	A. langeroni	*A. rutgersensis*
	A. lipmanii	*A. salmonicolor*
	A. maculatus	*A. sampsonii*
	A. odorifer	*A. sanfelicei*
	A. praecox	*A. setonii*
	A. purpeochromogenus	*A. sulphureus*
	A. reticuli	*A. tenuis*
	A. verne	*A. tumuli*
	A. xanthostroma	*A. tyrosinaticus*
		A. violaceus-caesari
		A. violaceus-ruber
		A. viridis
		A. viridochromogenus

Table II. The figures given are the averages of six diameters, one large and one small for each of three colonies. The flasks inoculated with *A. sulphureus* became heavily contaminated with a species of Penicillium and no results were, therefore, obtained for this filtrate.

TABLE II

SEVEN DAYS GROWTH OF *Colletotrichum gloeosporioides* IN AGAR PREPARED FROM VARIOUS FILTRATES, EXPRESSED IN AVERAGE DIAMETERS IN MILLIMETERS, OF THREE CULTURES

Organism from which Filtrate was Prepared	Diameter in mm.
Strong Inhibitors:	
A. oligocarbophilus	18.0
A. flavus Kr.	30.5
A. ruber	34.0
Weak Inhibitors:	
A. flavovirens	57.0
A. bobili	60.5
A. chromogenus	63.0
Non-inhibitors:	
A. canis	58.0
A. albosporeus	59.5
A. sulphureus	Contaminated
Controls:	
C. gloeosporioides	49.0
Uninoculated	62.5

The results of these experiments indicate that the growth of *Colletotrichum gloeosporioides* is greatly inhibited by the filtrates taken from strong inhibitors, but not at all by the filtrates from the week inhibitors or non-inhibitors.

If inhibition of fungous growth is due to a toxic substance manufactured in the medium by the Actinomycetes—and there is little question as to that—several theories can be proposed to explain the facts observed.

1. It may be reasonably assumed that the difference between inhibitors and non-inhibitors is the ability of some Actinomycetes to produce a substance toxic to the fungus and the inability of others to manufacture such a substance.

2. The difference between strong and weak inhibitors may be explained either on a quantitative or a qualitative basis or both. If the toxic substance produced by the inhibiting Actinomycetes is assumed to be identical or similar in all species, then the degree of inhibition caused by different species may be a measure of the amount of toxin formed in a given period of time, the strong inhibitors differing from the weak in the speed with which they manufacture the toxin.

If the inhibiting substance is different in each case, however, it may be that that produced by the strong inhibitors is thermostable while that produced by the weak inhibitors is thermolabile. This would explain why the filtrates from weak inhibitors produced no inhibitory effects on the growth of *C. gloeosporioides*.

Furthermore, it is possible that a combination of factors are responsible for the discrepancy shown in the behavior of the weak inhibitors directly through their colonies on agar and indirectly through their filtrates. If, for instance, we assume that these Actinomycetes manufacture a relatively small amount of toxin which is partially or totally thermolabile we would expect results similar to those obtained. The amount of toxin which emanated from the colonies growing on agar may have been sufficient to cause a small amount of inhibition on the neighboring fungous colony, but enough of the toxin may have been destroyed in the filtrates of the liquid cultures when these were subjected to autoclaving so that no inhibitory effects could be produced on the fungus growing on media prepared from such filtrates.

3. Growth of the fungus on its own filtrate agar was much slower as compared to that on the uninoculated controls, as well as that on the weak-inhibitor and non-inhibitor filtrate agars. This seeming autoinhibition may be explained partly on the basis of an accumulation of waste products of metabolism in the liquid culture, and partly on the basis of a partial food depletion of the medium. Previous experiments have shown that food depletion of the medium is not responsible for the inhibitory effects caused by *Actinomyces albus* Kr. and it is reasonable to suppose that this would hold true to a large extent for other Actinomycetes. *Colletotrichum gloeosporioides*, however, produces a much greater growth than any of the Actinomycetes tested and consequently probably uses much more food.

An autotoxic substance similar to the toxin produced by the Actinomycete inhibitors cannot be postulated for *C. gloeosporioides* since two colonies of the fungus growing in the same Petri dish do not inhibit each other, but merge.

In view of the results reported herein, it would be of interest to determine if the production of a fungus-inhibiting toxin by certain Actinomycetes is in any way indicative of the relationship of such species.

This work was carried on in 1939 while the writer, on leave of absence from Kent State University, Kent, Ohio, was associated with the Institut de Chimie et d'Agriculture "Nicolaos Canellopoulos" as plant pathologist, at Piraeus, Greece.

The writer is deeply grateful to Dr. K. Nevros, Director of the Institut for the excellent laboratory facilities placed at his disposal for this and other studies; to Miss Adamantia Kokole for her valuable assistance during the laboratory work; to the administrative authorities of Kent State University for extending to him a year's leave of absence for work in Greece, and to all others who in any way assisted him during the progress of this investigation.

THE PHYSIOLOGICAL ACTIVITY OF CERTAIN ALCOHOLS AND ETHERS TO GOLDFISH

By HARVEY C. BRILL
AND
ALEXANDER K. PRESNELL
Miami University, Oxford, Ohio

Many alcohols and ethers that were laboratory curiosities a decade or two ago are now produced in industrial quantities and much interest has developed among investigators and others as to their possible utilization. Further, a note by Reid Hunt on the toxicity of ethylene glycol[1] has led the authors to undertake a comparison of the physiological activities of various alcohols and ethers on goldfish. Since goldfish are convenient to handle, and are relatively prompt to respond to their environment, thus giving results that are reliable and comparable, they are frequently chosen as the agencies for such measurements.[2]

EXPERIMENTAL METHODS AND RESULTS

Since ordinary tap water is non-toxic to goldfish and none of the compounds in the series that were tested react with the dissolved salts, aerated tap water was used as the solvent in this study. Water distilled from tin vessels or stored in tin vessels has been found to be toxic to goldfish. In all experiments 250 cc. of solution per fish were used and unless otherwise stated three fish were simultaneously submerged for each test. Three fish were introduced simultaneously into 750 cc. of solution as consecutive introduction may lead to uncertain results. Apparently absorption of the solute takes place so that the concentration of the solution is lowered and longer time intervals would be necessary to produce anesthesia in those fish introduced later. Evidence of this effect is supported by the data in Table I. Small fish were selected for experiment since they respond more promptly than larger fish on account of the larger body area per unit weight, and unit body area is a factor in sensitivity to environment.

The fish were maintained in water at a temperature of 31° C. at all times—a convenient temperature to maintain for the summer season.

---

[1] Hunt. Ind. Eng. Chem. 24, 361 (1932).

[2] Adams, Ridla, Burnett and Dreger. J. A. C. S. 48, 1758, (1926).
Leffler and Brill. J. A. C. S. 55, 365 (1933).
Drake and Busbey. J. A. C. S. 54, 2930 (1932).

TABLE I

EFFECT OF FISH ON SOLUTION CONCENTRATION (ISOPROPIL ALCOHOL)

Concentration M/L	Fish No.		Time for Anesthesia	Time Before Removal	Condition At and After Removal
			TRIAL I		
0.35	1	Alcohol Isopropyl	3 min. 15 sec.	15 min, 15 sec.	Recovered extremely slowly.
0.35	2	" "	3 " 35 "	18 "	" " "
0.35	3	" "	3 " 50 "	20 "	Dead when removed.
0.35	4	" "	4 "	17 "	Recovered rather slowly.
			TRIAL II (Solution from Trial I)		
0.35	1	Alcohol Isopropyl	3 min. 50 sec.	18 min.	Recovered slowly.
0.35	2	" "	4 " 10	19 "	" "
0.35	3	" "	4 " 30 "	20 "	" "
0.35	4	" "	4 " 35 "	21 "	Recovered extremely slowly.
			TRIAL III (Solution from Trial II)		
0.35	1	Alcohol Isopropyl	4 min. 30 sec.	22 min.	Recovered slowly.
0.35	2	" "	4 " 40 "	24 "	" "
0.35	3	" "	5 "	26 "	Recovered very slowly.
0.35	4	" "	5 " 05 "	28 "	Dead when removed.

NOTE—Eastman Kodak Chemicals were used in most of the experiments.

In the first trial the average length of time for anesthesia to appear was 3 min. 40 sec., and 20 min. for death to take place; in the second trail the corresponding times are 4 min. 15 sec. and no fish died at 21 min. exposure; in the third trial the average time for anesthesia to take place on the four fish was 4 min. 50 sec. and death did not ensue until 28 min. of exposure. Each trial required a longer time than the preceding—rather conclusive evidence of a loss in concentration due to absorption of the solute as care was taken not to dilute the solution when new fish were introduced.

In the experiments recorded in the tables that follow all solutions were discarded after four fish had been submerged in them and new solutions made when needed.

Thus they were never subjected to abrupt changes in temperature which would make results more uncertain.

To determine the anesthetic state, a thermometer (weight 38.5 gms.) was allowed to rest on the tail of the fish. When no movement of the fish resulted from this pressure, it was concluded that anesthesia had set in.

Proof that aerated doubly distilled water as the solvent has no advantage over aerated tap water in such tests as are described is presented in Table II.

TABLE II

COMPARATIVE EFFECTS OF ETHYL ALCOHOL IN AERATED DOUBLY DISTILLED WATER AND AERATED TAP WATER ON GOLDFISH

Fish No.	Fish Size		Concentration of Sol.	Time for Anesthesia, min.	Time Before Removal, min.	Condition at and After Removal
	Length mm.	Weight gms.				
DOUBLY DISTILLED WATER						
1	41	2.1	M/L 0.4	65	70	Recovered
2	40	1.9	....	80	90	Recovered slowly
3	42	2.3	....	140	165	Remained anesthetized. Died later
TAP WATER						
1	42	2.3	0.4	57	65	Recovered slowly
2	39	1.8	....	75	85	Recovered slowly
3	42	2.3	....	100	175	Died later

The data in Table II do not indicate any determinable differences in doubly distilled and tap water as solvents for ethyl alcohol, and tap water has been used throughout the rest of the experiments.

Solutions were made up of such strengths that anesthesia took place in less than ten minutes. The length of time for death to result was also determined. These results are listed in Table III and those that follow.

TABLE III

EFFECTS OF MONOHYDROXY ALCOHOLS ON GOLDFISH

Alcohol	Concentration M/L	Fish No.	Fish Size		Time for Anesthesia	Time Before Removal	Condition At and After Removal
			Length mm.	Weight gms.			
Methyl	0.60	1	41	2.1	....	120 min.	No effect.
“	2.00	1	40	1.9	4 min.	5 “ 30 “	Recovered readily.
“	2.00	2	39	1.8	4 “ 50 “	7 “ 30 “	Died without recovery.
“	2.00	3	39	1.8	4 “ 55 “	9 “	Dead when removed.
Ethyl	0.40	1	42	2.3	57 min.	65 min.	Recovered readily.
“	0.40	2	39	1.8	75 “	85 “	Recovered slowly.
“	0.40	3	42	2.3	150 “	175 “	Died without recovery.
“	1.00	1	40	1.9	3 “ 10 sec.	4 “ 30 sec.	Recovered slowly.
“	1.00	2	43	2.5	4 “ 30 “	6 “ 35 “	Died without recovery.
“	1.00	3	42	2.3	6 “	9 “	Died without recovery.
n-Propyl	0.30	1	39	1.8	40 sec.	5 min. 30 sec.	Recovered.
“ “	0.30	2	38	1.6	45 “	7 “	Recovered slowly.
“ “	0.30	3	39	1.8	50 “	8 “	Died when removed.
“ “	0.15	1	39	1.8	4 min.	15 “ 30 sec.	Recovered.
“ “	0.15	2	39	1.8	4 “ 10 sec.	18 “ 30 “	Recovered very slowly.
“ “	0.15	3	39	1.8	5 “	21 “ 31 “	Dead when removed.
iso-Propyl	0.20	1	37	1.5	10 min. 30 sec.	45 min.	Recovered slowly.
“ “	0.20	2	39	1.8	17 “	48 “	Died without recovery.
“ “	0.20	3	37	1.5	18 “	52 “	Dead when removed.
“ “	0.35	1	37	1.5	3 “ 15 sec.	15 “ 15 sec.	Recovered extremely slowly.
“ “	0.35	2	39	1.8	3 “ 35 “	18 “	Recovered extremely slowly.
“ “	0.35	3	38	1.6	3 “ 50 “	20 “	Dead when removed.
“ “	0.35	4	38	1.6	4 “	14 “	Recovered rather slowly.

TABLE III—(Continued)

Alcohol	Concentration M/L	Fish No.	Fish Size		Time for Anesthesia	Time Before Removal	Condition At and After Removal
			Length mm.	Weight gms.			
n-Butyl	0.40	1	39	1.8	30 sec.	45 sec.	Died without recovery
" "	0.40	2	41	2.1	34 "	45 "	Died without recovery.
" "	0.40	3	41	2.1	40 "	45 "	Died without recovery.
" "	0.05	1	40	1.9	50 "	1 min. 15 "	Recovered slowly.
" "	0.05	2	40	1.9	1 min.	1 " 35 "	Recovered slowly.
" "	0.05	3	41	2.1	1 " 5 "	1 " 50 "	Died without recovery.
" "	0.040	1	38	1.6	1 min. 30 sec.	3 min. 30 sec.	Recovered.
" "	0.040	2	39	1.8	2 "	5 " 30 "	Recovered.
" "	0.040	3	40	1.9	2 " 10 sec.	7 " 30 "	Died without recovery. (Apparent anesthesia as gills stopped movement, but swimming movements continued.)
" "	0.035	1	38	1.6	9 " 35 "	15 "	Recovered.
" "	0.035	2	40	1.9	10 "	19 "	Recovered.
" "	0.035	3	41	2.1	11 "	22 "	Died without recovery.
iso-Butyl	0.01	1	38	1.6	....	90 min.	No effect.
" "	0.08	1	42	2.3	2 min. 20 sec.	3 " 30 sec.	Recovered promptly.
" "	0.08	2	40	1.9	2 " 20 "	5 " 30 "	Recovered promptly.
" "	0.08	3	43	2.5	2 " 30 "	7 " 30 "	Recovered promptly.
" "	0.08	4	41	2.1	2 " 20 "	9 " 30 "	Recovered very slowly.
" "	0.08	5	42	2.3	2 " 30 "	11 " 30 "	Recovered very slowly.
" "	0.08	6	42	2.3	2 " 30 "	13 " 30 "	Recovered very slowly.
" "	0.08	7	43	2.5	2 " 25 "	15 " 30 "	Recovered very slowly.
" "	0.08	8	42	2.3	2 " 30 "	17 " 30 "	Died without recovery.

TABLE III—(Continued)

Alcohol	Concentration M/L	Fish No.	Fish Size		Time for Anesthesia	Time Before Removal	Condition At and After Removal
			Length mm.	Weight gms.			
sec-Butyl	0.05	1	45	2.7	16 min.	31 min.	Recovered promptly.
" "	0.05	2	37	1.5	18 " 30 sec.	38 "	Recovered slowly.
" "	0.05	3	44	2.6	19 "	45 "	Recovered slowly.
" "	0.10	1	38	1.6	2 " 35 "	6 " 30 sec.	Recovered promptly.
" "	0.10	2	37	1.6	2 " 35 "	7 " 30 "	Recovered promptly.
" "	0.10	3	38	1.6	2 " 45 "	8 " 30 "	Recovered very slowly.
" "	0.10	4	38	1.6	2 "	10 " 30 "	Recovered very slowly.
" "	0.10	5	39	1.8	2 " 50 "	18 "	Recovered very slowly.
" "	0.10	6	38	1.6	2 " 40 "	21 "	Dead when removed.
tert-Butyl	0.10	1	38	1.6	20 min.	40 min.	Recovered very slowly.
" "	0.10	2	38	1.6	23 "	50 "	Recovered very slowly.
" "	0.10	3	39	1.8	27 "	60 "	Dead when removed.
" "	0.20	1	39	1.8	4 "	11 "	Recovered slowly.
" "	0.20	2	38	1.6	4 " 15 sec.	16 "	Recovered slowly.
" "	0.20	3	40	1.9	5 " 15 "	21 "	Recovered very slowly.
" "	0.20	4	39	1.8	4 " 25 "	26 "	Dead when removed.
Benzyl	0.25	1	38	1.6	Less than 20 sec.	30 sec.	Dead when removed.
"	0.05	1	38	1.6	20 sec.	30 "	Recovered slowly.
"	0.005	1	40	1.9	7 min.	19 min.	Recovered promptly.
"	0.0075	1	40	1.9	2 " 10 sec.	10 "	Recovered promptly.
"	0.0075	2	39	1.8	2 " 15 "	20 "	Recovered promptly.
"	0.0075	3	40	1.9	2 " 30 "	45 "	Recovered less promptly.
"	0.0075	4	40	1.9	2 " 20 "	60	Recovered less promptly.
"	0.0075	5	40	1.9	2 " 25 "	75 "	Recovered less promptly.
"	0.0075	6	39	1.8	2 " 20 "	90 "	Recovered less promptly.
"	0.0075	7	39	1.8	2 " 30 "	105 "	Recovered slowly.
"	0.0075	8	39	1.8	2 " 20 "	120 "	Dead when removed.

Not much comment is needed on the results of the experiments that are recorded in Table III.

Picaud is reported by Frankel[3] as finding the following ratios of toxicities on dogs for the normal alcohols when ethyl alcohol is given a value of 1.

TABLE IV

COMPARATIVE TOXICITIES OF ALCOHOLS TO FISH

Alcohols	Picaud	Our Results
Methyl	⅔	½
Ethyl	1	1
n-Propyl	2	3
n-Butyl	3	20
iso-Propyl	....	1½
iso-Butyl	....	5
sec-Butyl	....	5
tert-Butyl	....	5
Benzyl	....	20

These results agree quite well except those for n-butyl alcohol.

TABLE V

COMPARATIVE NARCOTIC EFFECTS OF ALCOHOLS

Alcohols	Schneegans and Mering on Dogs[4]	Our Results on Fish
Methyl	Indecisive	½ (?)
Ethyl	1	1
n-Propyl	1	6
iso-Propyl	6	4
n-Butyl	2	25
iso-Butyl	....	12
sec-Butyl	3	10
tert-Butyl	3	5
Benzyl	....	125

The narcotic effects for the butyl alcohols are contrary to the statement attributed to Mering by Frankel[5] who is reported as finding that primary alcohols are less active narcotics than secondary alcohols and these less active than tertiary alcohols.

These differences in results may possibly be due to a difference in methods of administration on the experimental animals used or to both.

---

[3] Frankel, Die Arzneimittel-Synthese, Fourth Ed. (1919). Julius Springer, Berlin p. 132.

[4] Loc. cit. p. 473.

TABLE VI

EFFECTS OF GLYCOLS AND GLYCEROL ON GOLDFISH

Compound	Concentration M/L	Fish No.	Fish Size		Time for Anesthesia	Time Before Removal, min.	Condition At and After Removal
			Lgth mm.	Wgt. gms.			
Ethylene glycol	4.0	1	37	1.5	10 min.	13 min.	Recovered slowly.
" "	4.0	2	38	1.6	11 "	15 "	Died without recovery.
" "	4.0	3	39	1.8	11 " 30 sec.	17 "	Dead when removed. (Anesthesia incomplete in all three cases.)
Propylene glycol	1.0	1	37	1.5	....	60 min.	No effect in 60 minutes.
" "	3.0	1	38	1.6	12 "	27 "	Died 2 hours later.
" "	3.0	2	38	1.6	13 "	30 "	Died later.
" "	3.0	3	40	1.9	15 "	33 "	Died later.
" "	3.0	4	38	1.6	12 " 30 sec.	24 "	Recovered readily. (Anesthesia incomplete in all cases.)
Trimethylene glycol	1.0	1	38	1.6	6 min.	15 min.	Recovered very slowly.
"	1.0	2	39	1.8	6 "	19 "	Recovered very slowly.
"	1.0	3	38	1.6	6 " 30 sec.	23 "	Recovered very slowly.
"	1.0	4	38	1.6	6 " 40 "	27 "	Died later. (Anesthesia incomplete in all cases.)
Glycerol.........	2.0	1	40	1.9	16 min.	17 min.	Died later.
"	2.0	2	39	1.8	19 "	20 "	Recovered slowly.
"	2.0	3	40	1.9	17 "	18 "	Recovered slowly. (Anesthesia incomplete in all cases.)

A study of the data in Table VI leads to the conclusion that the glycols and glycerol are not anesthetic to goldfish and that glycol is the least toxic to goldfish of the group investigated. These effects are in accord with a statement in Fränkel. (3d)

3d) (Loc. cit. p. 452).

TABLE VII

EFFECTS OF SEVERAL ETHERS ON GOLDFISH

Compound	Concentration M/L	Fish No.	Fish Size		Time for Anesthesia	Time Before Removal	Condition At and After Removal
			Lgth mm.	Wgt. gms.			
Diethyl ether....	0.30	1	38	1.6	20 sec.	1 min.	Recovered promptly.
" "	0.30	2	41	2.1	30 "	1 " 30 sec.	Recovered promptly.
" "	0.30	3	43	2.5	30 "	2 "	Recovered slowly.
" "	0.15	1	37	1.5	40 "	1 " 20 sec.	Recovered promptly.
" "	0.15	2	41	2.1	47 "	1 " 40 "	Recovered promptly.
" "	0.15	3	41	2.1	58 "	2 "	Recovered slowly.
" "	0.05	1	38	1.6	5 "	11 " 30 sec.	Recovered promptly.
" "	0.05	2	42	2.3	5 "	16 "	Recovered promptly.
" "	0.05	3	42	2.8	6 " 15 sec.	36 "	Recovered slowly.
" "	0.05	4	42	2.3	6 " 20 "	105 "	Recovered slowly.
" "	0.05	5	41	2.1	6 " 30 "	120 "	Dead when removed.
B, B'-dihydroxy-diethyl ether	0.6	1	38	1.6	....	25 min.	No effect.
" "	2.0	1	38	1.6	....	25 "	No effect.
" "	3.0	1	39	1.8	8 min.	17 "	Recovered very slowly.
" "	3.0	2	41	2.1	8 "	19 "	Dead when removed.
" "	3.0	3	41	2.1	8 " 30 sec.	21 "	Dead when removed. (Anesthesia incomplete in all cases.)
Ethylene glycol monoethyl ether	0.6	1	37	1.5	1 min. 55 sec.	11 min. 30 sec.	Recovered very slowly.
" "	0.6	2	37	1.5	2 " 10 "	13 " 30 "	Dead when removed.
" "	0.6	3	37	1.5	2 " 15 "	15 " 30 "	Dead when removed. (Anesthesia complete.)
Diethylene glycol monoethyl ether	1.0	1	38	1.6	2 min.	8 min.	Recovered slowly.
" "	1.0	2	39	1.8	2 "	9 "	Recovered slowly. (Decidedly groggy end 5½ hours.)
" "	1.0	3	40	1.9	2 " 30 sec.	10 "	Dead when removed.

The results with the ethers are readily predictable. The presence of free hydroxyl groups lowers the narcotic powers of the ethers.

Mering used dogs and employed hypodermic injection. Our results would be governed by the amount of topical absorption which is dependent on relative solubility of a particular alcohol in water and fish tissue and the activity of the alcohol after absorption. There may be a marked difference in the distribution coefficients of isomeric alcohols. This problem might warrant further study.

A similar statement is found in Percy May's "The Chemistry of Synthetic Drugs."[6]

Benzyl alcohol has an enhanced narcotic effect over ethyl alcohol in comparison with its increase of toxicity, the ratio for ethyl alcohol (narcotic effect/toxicity) being one while that for benzyl alcohol is five.

A comparative measurement of the toxicities and narcotic activities to goldfish of methyl, ethyl, propyl (iso- and normal), butyl (normal-, iso, secondary-, and tertiary-) and benzyl alcohols; of ethylene, propylene, and trimethylene glycols, and of glycerol; and of diethyl, $\beta\beta$-dihydroxydiethyl, ethyleneglycol-monoethyl, and diethyleneglycol-monoethyl ethers has been made. The results are not in all cases in agreement with the data recorded in the chemical literature.

CONCLUSIONS

1. The toxicity of normal-butyl alcohol has been found to be higher than that recorded in the literature. The comparative toxicities of the different butyl alcohols is in disagreement with those recorded in the literature. Likewise their narcotic activities are not in accord with the recorded activities. Introduction of hydroxyl groups lowers the narcotic activity and in some cases causes it entirely to disappear.

---

[5] Loc. cit. p. 133.

[6] May, Percy and Dyson, G. M. The Chemistry of Synthetic Drugs, Fourth Ed. Rev. (1939). (Longman's Green and Company, London, pp. 23 and 56).

Man

Like many other British books appearing these days, this one is made up of a collected set of the author's essays garnered from those published over a period of years as isolated writings. Unlike some others, however, this volume has a certain continuity of thought and singleness of purpose. The author finds that the war, with its necessary social changes, has served to tie together the lines of thought developed throughout the several essays, and to point the way towards a socio-biological outlook for the recreation of civilization after the war. The essays run the gamut of evolution, eugenics, anatomy, physiology, ecology, psychology, the concept of race, and religion. Each is challenging in the way only a Huxley could challenge. Scientist and layman alike will be the better informed for having read the book.—*L, H. S.*

Man Stands Alone, by J. S. Huxley. x+297 pp. New York, Harper and Brothers, 1941. $2.75.

PARASITES FROM FISH OF BUCKEYE LAKE, OHIO

RALPH V. BANGHAM,
College of Wooster,
Wooster, Ohio

During the summer of 1930 a study was made of the parasitism of the fish of Buckeye Lake as a part of a survey conducted by the Ohio Division of Conservation.

Buckeye Lake is located in portions of Licking, Fairfield and Perry Counties. It is a long irregular body of water seven and one-half miles east to west, varying in width from one-fourth mile in the east to one and one-half mile in the widest portion of the west end. It covers an estimated area of 4,200 acres. The water-shed is a low table land three to five miles wide. Several small streams enter and the lake drains through a waste weir into the south fork of the Licking River. The lake was originally flooded and dikes maintained to supply water for a portion of the Ohio Canal system. There are many shallow areas filled with vegetation. The bottom is mainly composed of soft mud although in areas where dredging operations are conducted, sand and gravel is coming in.

There are several small islands, one of the largest being of a peculiar formation. It is an anchored, floating sphagnum peat bog of approximately forty acres. There are numerous small ponds on the southwest end of the island. One of these ponds was selected as a seining station. It contained young carp, three species of bullheads, and mud minnows. These fish were infected with larval *Spiroxys* sp.

There were thirty-nine additional seining stations where visits were made every two weeks and seine hauls taken with a fifty foot net where vegetation and bottom conditions would permit. In case the larger net could not be used, a fifteen foot seine was substituted. A fyke net was also set in different locations for ten day periods and lifted twice daily. Forty-eight hundred fish from this net were identified, measured, tagged and released. A few were retained for examination of their parasites. Certain fish not taken by other methods were secured in gill nets.

Fish were examined while the parasites were living, then parasites were preserved and later stained, mounted and identified. Five hundred and four fish belonging to thirty-eight species were examined. Of this number 334 or 66.2 per cent were parasitized. This is a somewhat higher degree of infection than that found by Bangham and Hunter (1939), for parasites of Lake Erie fish. There, 2156 fish belonging to 79 species yielded a 58.3 per cent infection with at least one parasitic species. There were fewer different species of parasites in Buckeye Lake fish but a heavier infection of parasitic protozoa, copepods and cysts of larval Acanthocephala was found. In 1938, the writer examined 1380 fish belonging to 45 species from southern Florida and found 88.2 per cent parasitized, (Bangham, in press). Here the increase in parasitism was chiefly due to large numbers of encysted trematode metacercariae and larval nematodes which have their adult stages in fish-eating birds. More different species of parasites were encountered in a study in 1939 of fish of Algonquin Park lakes. In this area, 560 fish belonging to 22 species were examined and 84.3 per cent were infected (Bangham, in press). In this region water birds also play an important part in the life cycles of many of the fish parasites.

At Buckeye Lake the gills of fish were frequently infested by parasitic copepods and less often by gill flukes. Channel catfish, small-mouth bass and large-mouth bass in several instances carried cysts of myxosporidian forms on their gill filaments. A sporozoan encysted in the body cavities of young gizzard shad was the only parasite found in this fish species. This form was found in ten of twelve young gizzard shad when examined in the fall. This form apparently caused the death of numerous young gizzard shad.

Trematodes were not as numerous as in the same species of fish from Lake Erie. There were but few encysted strigeids and the infections were usually light. Moderately heavy infestations of gill flukes belonging to the family Gyrodactylidae were found on the tallow-mouthed minnow, tadpole madtom, mud pickerel, small-mouth bass, large-mouth bass, green sunfish, bluegill, pumpkinseed, white crappie and white bass. Another group of gill trematodes was represented by a single specimen of *Octobothrium* sp. taken from the tallow-mouthed minnow. *Paramphistomum stunkardi* Holl was found in small numbers in individuals belonging to six species of Buckeye Lake fish. This trematode was described by Holl (1929) from the pumpkinseed and warmouth bass of North Carolina. It was reported by

Venard (1940) from ten species of fish. Buckeye Lake represents the most northern record reported in the distribution of this parasite.

Cestodes belonging to the family Caryophyllaeidae were fairly numerous in common suckers, hog suckers, carp and satin-finned minnows. Unfortunately most of the specimens were lost before they were stained and identified. The only record of the family Bothriocephilidae was a single specimen of *Bothriocephalus formosus* secured from a Johnny darter. This species was described by Mueller and Van Cleave (1932) from the trout perch of Oneida Lake. In 1934, Van Cleave and Mueller included the Johnny darter as another host of this cestode. Three species of adult cestodes belonging to the genus Proteocephalus were found, *P. pinguis* in the mud pickerel, *P. pearsei* in seven species and *P. ambloplitis* in a few small-mouth and large-mouth bass. Larval stages of this latter cestode were encysted in ten fish species but the infections were light.

The nematodes are represented by several species but always in small numbers. Acanthocephala were secured in greater abundance. Encysted *Leptorhynchoides thecatus* (Linton) were taken from 15 fish species while adults were secured from the intestinal tracts of 13. Larval *Neoechinorhynchus cylindratus* (Van Cleave) were encysted in the livers of blue gills and pumpkinseeds while adults of this acanthocephalan were carried by large-mouth and small-mouth bass and green sunfish.

In the list of fish hosts and their parasites which follow, the parasites are listed in order of abundance, the number in parenthesis following the species indicates the number of individuals carrying the designated parasite. The asterisk preceding the name of the parasite indicates an immature stage (usually an encysted form).

1. *Dorosoma cepedianum* (Le Sueur). Gizzard shad.
    (Examined, 17. Parasitized, 5.)
        Microsporidia (5).
2. *Carpiodes cyprinus cyprinus* (LeSueur). Carp sucker.
    (Examined, 3. Parasitized, 0.)
3. *Catostomus commersonnii commersonnii* (Lacépède).
    Common sucker.
    (Examined, 23. Parasitized, 19.)
        Glaridacris catostomi Cooper (15).
        Biacetabulum infrequens Hunter (5).
        Leptorhynchoides thecatus (Linton) (1).
        Ergasilus versicolor Wilson (1).

4. *Hypentelium nigricans* (LeSueur). Hog sucker.
   (Examined, 2. Parasitized, 1.)
      Caryophyllaeidae (1).
5. *Erimyzon sucetta kennerlii* (Girard). Chub sucker.
   (Examined, 9. Parasitized, 5.)
      Neoechinorhynchus crassus Van Cleave (5).
      Ergasilus versicolor Wilson (1).
      Ergasilus centrarchidarum Wright (1).
      Ergasilus caeruleus Wilson (1).
6. *Moxostoma erythrurum* (Rafinesque). Golden sucker.
   (Examined, 1. Parasitized, 0.)
7. *Cyprinus carpio* Linnaeus. Carp.
   (Examined, 17. Parasitized, 8.)
      Caryophyllaeidae (7).
      **Spiroxys* sp. (1).
8. *Semotilus atromaculatus atromaculatus* (Mitchill). Creek chub.
   (Examined, 4. Parasitized, 3.)
      **Neascus vancleavei* (3).
9. *Notemigonus crysoleucas auratus* Rafinesque.
   (Examined, 7. Parasitized, 0.)
10. *Notropis deliciosus stramineus* (Cope). Northern sand shiner.
    (Examined, 7. Parasitized, 2.)
       Caryophyllaeidae (1).
       Allocreadium lobatum Wallin (1).
11. *Notropis spilopterus* (Cope). Satin-finned shiner.
    (Examined, 17. Parasitized, 2.)
       **Proteocephalus* sp.
       **Neascus vancleavei* (Agersborg).
12. *Notropis cornutus chrysocephalus* (Rafinesque). Mississippi common shiner.
    (Examined, 1. Parasitized, 0.)
13. *Ericymba buccata* Cope. Silver-jawed minnow.
    (Examined, 5. Parasitized, 0.)
14. *Hyborhynchus notatus* (Rafinesque). Blunt-nosed minnow.
    (Examined, 19. Parasitized, 9.)
       **Neascus vancleavei* (Agersborg) (9).
15. *Campostoma anomalum anomalum* (Rafinesque). Ohio tallow-mouthed minnow.
    (Examined, 7. Parasitized, 5.)
       **Neascus vancleavei* (Agersborg) (3).
       Octobothrium sp. (2).
       Allocreadium lobatum Wallin (2).
       Gryodactylidae (1).
       **Aganomena* sp. (1).
16. *Ictolurus lacustris punctatus* (Rafinesque). Southern channel catfish.
    (Examined, 15. Parasitized, 15.)
       Ergasilus versicolor Wilson (13.)

Corallobothrium fimbriatum Essex (9).
Henneguya exilis Kudo (3).
Corallobothrium giganteum Essex (1).
**Proteocephalus ambloplitis* (Leidy) (1).
Leptorhynchoides thecatus (Linton) (1).
Achtheres micropteri Wright (1).

17. *Ameiurus melas melas* (Rafinesque). Black bullhead.
(Examined, 17. Parasitized, 14.)
**Proteocephalus ambloplitis* (Leidy) (7).
Corallobothrium fimbriatum Essex (5).
Ergasilus versicolor Wilson (5).
**Spiroxys* sp. (4).
**Leptorhynchoides thecatus* (Linton) (1).

18. *Ameiurus nebulosus nebulosus* (LeSueur). Brown bullhead.
(Examined, 14. Parasitized, 10.)
Ergasilus versicolor Wilson (7).
**Proteocephalus ambloplitis* (Leidy) (6).
Corallobothrium fimbriatum Essex (4).
Leptorhynchoides thecatus (Linton) (2).

19. *Ameiurus natalis natalis* (LeSueur). Yellow bullhead.
(Examined, 11. Parasitized, 11.)
Leptorhynchoides thecatus (Linton) (7).
**Spiroxys* sp. (6).
Ergasilus versicolor Wilson (5).
Alloglossidium geminus (Mueller) (3).
Corallobothrium fimbriatum Essex (2).
**Camallanus* sp. (2).
Phyllodistomum staffordi Pearse (2).
Paramphistomum stunkardi Holl (1).

20. *Schilbeodes gyrinus* (Mitchill). Tadpole madtom.
(Examined, 15. Parasitized, 13.)
**Leptorhynchoides thecatus* (Linton) (7).
Gyrodactylidae (6).
Corallobothrium fimbriatum Essex (5).
**Spiroxys* sp. (3).
Alloglossidium corti (Lamont) (2).
Ergasilus caeruleus Wilson (1).
**Proteocephalus ambloplitis* (Leidy) (1).

21. *Esox vermiculatus* LeSueur. Mud pickerel.
(Examined, 18. Parasitized, 13.)
Leptorhynchoides thecatus (Linton) (6).
**Leptorhynchoides thecatus* (Linton) (6).
Paramphistomum stunkardi Holl (4).
Proteocephalus pinguis La Rue (3).
Macroderoides flavus Van Cleave and Mueller (2).
Gyrodactylidae (1).
Microphallus ovatus Osborn (1).

22. *Umbra limi* (Kirtland). Western mud-minnow.
(Examined, 4. Parasitized, 4.)

  - **Spiroxys* sp. (4).
  - *Hepaticola bakeri* Mueller and Van Cleave (2).

23. *Fundulus notatus* (Rafinesque). Black-striped topminnow.
    (Examined, 11. Parasitized, 5.)
    - **Leptorhynchoides thecatus* (Linton) (3).
    - **Agamomema* sp. (1).
    - **Proteocephalus* sp. (1).
24. *Labidesthes sicculus sicculus* (Cope). Northern brook silverside.
    (Examined, 6. Parasitized, 0.)
25. *Perca flavescens* (Mitchill). Yellow perch.
    (Examined, 17. Parasitized, 7.)
    - **Neascus amblopiitis* Hughes (5).
    - **Leptorhynchoides thecatus* (Linton) (3).
    - *Proteocephalus pearsei* La Rue (1).
    - **Neascus* sp. (1).
    - **Agamonema* sp. (1).
26. *Boleosoma nigrum nigrum* Rafinesque. Western Johnny darter.
    (Examined, 8. Parasitized, 1).
    - *Bothriocephalus formosus* Van Cleave and Mueller (1).
27. *Percina caprodes caprodes* (Rafinesque). Ohio log perch.
    (Examined, 12. Parasitized, 7.)
    - **Leptorhynchoides thecatus* (Linton) (5).
    - **Neascus* sp. (3).
    - Microsporidia (3).
    - **Camallamus* sp. (2).
28. *Poecilichthys caeruleus* (Storer). Rainbow darter.
    (Examined, 3. Parasitized, 2.)
    - **Leptorhynchoides thecatus* (Linton) (2).
29. *Poecilichthys exilis* (Girard). Iowa darter.
    (Examined, 12. Parasitized, 12.)
    - **Leptorhynchoides thecatus* (Linton) (12).
30. *Micropterus dolomieu dolomieu* (Lacépède). Small-mouth bass.
    (Examined, 34. Parasitized, 29.)
    - **Proteocephalus ambloplitis* (Leidy) (15).
    - *Ergasilus centrarchidarum* Wright (13).
    - *Leptorhynchoides thecatus* (Linton) (10).
    - **Leptorhynchoides thecatus* (Linton) (7).
    - *Neochinorhynchus cylindratus* (Van Cleave) (4).
    - Myxosporidia (gill cysts) (4).
    - *Ergasilus caeruleus* Wilson (2).
    - *Proteocephalus ambloplitis* (Leidy) (2).
    - *Proteocephalus pearsei* LaRue (2).
    - *Achtheres micropteri* Wright (1).
    - **Camallanus* sp. (1).
    - **Agamomema* sp. (1).
    - *Crepidostomum cornutum* (Osborn) (1).
    - *Paramphistonum stunkardi* Holl (1).
    - **Neascus ambloplitis* Hughes (1).
    - Gyrodactylidae (1).

31. *Huro salmoides* (Lacépède). Large-mouth bass.
(Examined, 38. Parasitized, 38.)
Neoechinorhynchus cylindratus (Van Cleave) (18).
**Leptorhynchoides thecatus* (Linton) (18).
Ergasilus centrarchidarum Wright (15).
Myxosporidia (gill cysts) (14).
Leptorhynchoides thecatus (Linton) (12).
**Proteocephalus ambloplitis* (Leidy) (7).
Proteocephalus pearsei LaRue (4).
Gyrodactylidae (3).
**Neascus ambloplitis* Hughes (1).
Paramphistomum stunkardi Holl (1).
Ergasilus caeruleus Wilson (1).
Proteocephalus ambloplitis (Leidy) (1).
32. *Lepomis cyanellus* Rafinesque. Green sunfish.
(Examined, 15. Parasitized, 15.)
**Leptorhynchoides thecatus* (Linton) (15).
Paramphistomum stunkardi Holl (7).
Camallanus oxycephalus Ward and Magath (3).
**Proteocephalus ambloplitis* (Leidy) (2).
Gyrodactylidae (2).
Ergasilus caeruleus Wilson (2).
Leech (1).
Proteocephalus pearsei LaRue (1).
**Agamomema* sp. (1).
Anallocreadium sp. (1).
Glochidia (gill cysts) (1).
33. *Lepomas megalotis megalotis* (Rafinesque). Southern long-eared sunfish.
(Examined, 4. Parasitized, 4.)
**Leptorhynchoides thecatus* (Linton) (4).
Paramphistomum stunkardi Holl (3).
**Proteocephalus ambloplitis* (Leidy) (1).
Leptorhynchoides thecatus (Linton) (1).
34. *Lepomis gibbosus* (Linn.). Pumpkinseed.
(Examined, 20. Parasitized, 20.)
Ergasilus caeruleus Wilson (15).
**Leptorhynchoides thecatus* (Linton) (10).
**Neoechinorhynchus cylindratus* (Van Cleave) (5).
Leech (3).
Gyrodactylidae (3).
Anallocreadium sp. (1).
**Proteocephalus ambloplitis* Leidy (1).
Proteocephalus pearsei LaRue (1).
Myxosporidia (1).
Ergasilus centrarchidarum Wright (1).
Leptorhynchoides thecatus (Linton) (1).
35. *Lepomis macrochirus* Rafinesque. Bluegill.
(Examined, 39. Parasitized, 34.)
Ergasilus centrarchidarum Wright (20).

*_Proteocephalus ambloplitis_ (Leidy) (15).
*_Leptorhynchoides thecatus_ (Linton) (12).
Ergasilus caeruleus Wilson (9).
Camallanus oxycephalus Word and Magath (6).
Spinitectus carolini Holl (5).
*_Neoechinorhynchus cylindratus_ (Van Cleave) (5).
Leptorhynchoides thecatus (Linton) (3).
Gyrodactylidae (3).
Neascus vancleavei (Agersborg) (2).
*_Agamomema_ sp. (2).
Leech (2).

36. _Pomoxis annularis_ Rafinesque. White crappie.
(Examined, 23. Parasitized, 7.)
Cryptogonimus chyli Osborn (4).
*_Leptorhynchoides thecatus_ (Linton) (2).
Ergasilus caeruleus Wilson (1).
Leech (1).
Gyrodactylidae (1).
*_Proteocaphalus ambloplitis_ (Leidy) (1).
Leptorhynchoides thecatus (Linton) (1).

37. _Pomoxis nigro-maculatus_ (LeSueur). Black crappie.
(Examined, 2. Parasitized, 2.)
*_Neascus vancleavei_ (Agersborg) (2).
Cryptogonimus chyli Osborn (1).
Proteocephalus pearsei (1).

38. _Lepibema chrysops_ (Rafinesque). White bass.
(Examined, 27. Parasitized, 12.)
Gyrodactylidae (4).
Proteocephalus pearsei LaRue (4).
Leptorhynchoides thecatus (Linton) (4).
Argulus stizostethii Kellicott (3).
Camallanus oxycephalus Ward and Magath (2).
*_Corallobothrium_ sp. (1).

LITERATURE CITED

Bangham, R. V. (in press) Parasites of fish of Algonquin Park Lakes. Trans. An. Fish Soc., 1940. Vol. 70. In press.

1940. (in press) Parasites of freshwater fish from Southern Florida. Proc. Fla. Acad. Sci. Vol. 5. In press.

Bangham, R. V., and G. W. Hunter, III. 1939. Studies on fish parasites of Lake Erie. Distribution studies. Zoologica, Vol. 24. pp. 385–448.

Holl, F. J. 1929. A Paramphistome from fishes. Journ. Parasitol., Vol. 16. pp. 35–37.

Mueller, J. F., and H. J. Van Cleave. 1932. Parasites of Oneida Lake fishes. Part 2. Descriptions of new species and some general taxonomic considerations, especially concerning the trematode family Heterophyidae. Roosevelt Wild Life Annals, Vol. 3. pp. 77–137.

Van Cleave, H. J., and J. F. Mueller. 1934. Parasites of Oneida Lake fishes. Part III. A biological and ecological survey of the worm parasites. Roosevelt Wild Life Annals. pp. 161–334.

Venard, C. E. 1940. Studies on parasites of Reelfoot Lake fish. I. Parasites of the large-mouthed black bass, _Huro salmoides_ Lacépède. Rept. Reelfoot Lake Biol. Sta., Vol. 4, pp. 43–63.

RELATION OF SAUGER CATCH TO TURBIDITY IN LAKE ERIE

KENNETH H. DOAN,
Franz Theodore Stone Laboratory,
The Ohio State University

Studies of meteorological and limnological conditions reveal that factors other than intensity of fishing may relate to the abundance of certain fishes in Lake Erie. Present investigations point to the importance of turbidity of water as a determinant of future availability of the sauger, *Stizostedion canadense* (Smith), to commercial operations in Ohio.

This research has been conducted at the Franz Theodore Stone Laboratory of The Ohio State University, under the direction of Dr. T. H. Langlois and members of the staff, and has received full help and co-operation from the Ohio Division of Conservation and Natural Resources. Monthly averages of the turbidity of Lake Erie, 3 miles off Cleveland, have been furnished through the kindness of Mr. Clyde Irwin, chemist at the Baldwin Filtration Plant in Cleveland.

The sauger constitutes about 7% of the total Ohio Commercial catch in Lake Erie. About 67% of these saugers are taken in trap nets, and 82% of the 1939 poundage was taken in the spring season in that portion of Ohio waters west of Fairport. These considerations have prompted inquiry into the relation between the sauger catch, the number of trap nets, and turbidity conditions in the spring.

At first, knowing that the greater part of the sauger catch was made with trap nets, the number of nets licensed and the total commercial poundage of saugers were compared from 1927 through 1939. (Table I). The correlation is quite insignificant. Also, variation in the sauger catch is greater than in the number of nets, indicating the possible influence of some factor other than intensity of fishing upon the abundance of fish.

April and May are the months in which saugers spawn and the fry hatch, in western Lake Erie. Supposing that there was a relation between the muddiness of the water and the success of spawning and survival of the young, evidence of this success should be apparent in the commercial catches after such time as the fish have attained the minimum legal length of 11 inches, which is when they are 3 years of age (2). In most seasons, 3-year-old fish are dominant in commercial catches. (Table II). Following such a course of reasoning, a statistically significant (1, 3, 4,) positive coefficient of correlation of 0.79 was found

TABLE I

The Sauger Catch is the Total Commercial Poundage Taken in the Ohio Waters of Lake Erie. The Number of Nets Represents the Sum of Both Spring and Fall Trap Net Licenses. Turbidities are the Mean April-May Averages at Cleveland. Precipitation is the Mean Rainfall for April-May at Toledo, Sandusky and Cleveland.

Year	Saugers, Lbs., Uncorrected for Number of Nets A	Saugers, Corrected, Lbs., 0000 Omitted B	Number of Nets C	Turbidity, p. p. m. D	Precipitation, Inches E
1927	1,144,197	124	6,939	22	5.7
1928	1,491,867	143	7,853	25	4.1
1929	1,528,887	156	7,356	44	9.9
1930	1,482,396	164	6,780	20	4.5
1931	1,726,528	181	7,166	9	5.4
1932	3,094,284	317	7,342	10	4.8
1933	2,124,111	218	7,333	23	7.1
1934	737,708	81	6,876	6	4.6
1935	1,479,410	147	7,543	(24) 6	4.2
1936	1,703,999	159	8,064	9	3.8
1937	1,172,194	102	8,648	18	6.9
1938	802,075	75	8,069	13	6.3
1939	1,661,269	160	7,793	....	....

Between D and A 3 yrs. later: $r = +0.79$ $z = 1.06$ $\sigma z = \pm 0.38$
$bAD = 49.8$ $aA = 732$

Between D and B 3 yrs. later (1927–'36) $r = +0.82$ $z = 1.15$ $\sigma z = \pm 0.38$

$rCA = -.002$ (Not signif.) rDE (1927–'38) $= +0.60$

TABLE II

Numbers and Ages of Fish in Samples of Ohio Commercial Saugers, Lake Erie. Minimum Legal Length, 11 Inches.

Year	2 an	3 an	4 an	5 an
1937................	0	12	10	0
1938................	1	10	26	5
1939................	0	140	82	2

between the mean April-May turbidities and Ohio sauger catches 3 years later, from 1927 to 1936. (Fig. 1). Correction of the catch figures, to allow for the various numbers of nets fished in different years, gives a correlation coefficient of +0.82, between

April-May turbidities and sauger catches 3 years later. These coefficients do not differ statistically.

There are various influences upon the turbidity of a lake. Nature of the shores, depth, the direction of the long axis of the lake in relation to the magnitude and direction of winds, and precipitation may all affect the turbidity of the water. Several rivers enter western Lake Erie along the south shore. These rivers flow through the rich soil of highly cultivated farmlands, and after every rain carry a heavy load of suspended matter into the lake. A statistically significant r of $+0.60$ was found between the mean April-May precipitation at Toledo, Sandusky and Cleveland (5) and the mean April-May turbidity at Cleveland, from 1927 to 1938. Perhaps the precipitation did not affect the turbidity of the lake through turbid river inflow, as suggested, but that rainy weather was accompanied by high winds which stirred up the sediments in the shallower parts of the lake. In any event, by no matter how many degrees of relationship removed, a connection between precipitation and turbidity is apparent.

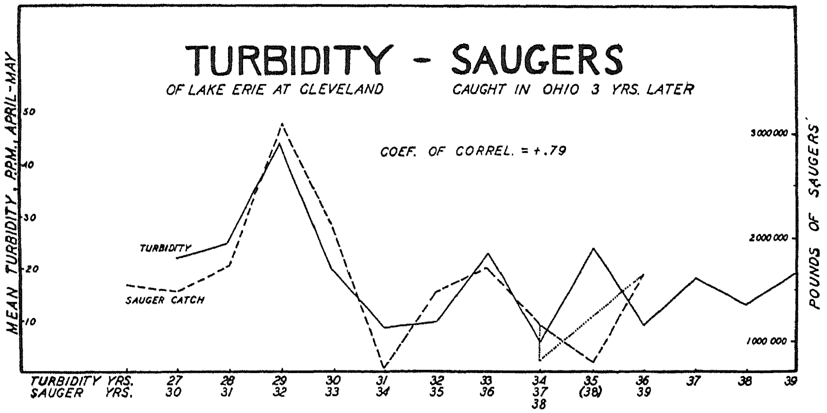


FIG. 1 Graph illustrating the relationship between mean April-May turbidities of Lake Erie off Cleveland and the Ohio commercial catch of saugers three years later. The 1938 catch, as well as that of 1937, were largely of the same dominant year class of 1934 (see Table II), and both relate to the turbidity of 1934 as indicated by the dotted line.

Three possible explanations to account for good sauger catches in Ohio 3 years after high spring turbidity may be suggested:

(1) The young saugers may, in clouded water, receive

protection from predators feeding chiefly by sight. A higher survival in turbid water would result.

(2) Limnological work at present being conducted by Dr. D. C. Chandler at the Stone Laboratory indicates that during periods of low light penetration, including high turbidity, microcrustacea are closer to the top than when the water is clear and more freely penetrable by light. Sauger fry feed near the surface when they are small, and so would have available a greater concentration of food under turbid conditions than when the water is clearer, with the plankton scattered down about 5 meters. Better feeding should promote a higher survival.

(3) Hatchery practice sometimes involves the use of powders, chalk or humus, to coat eggs which would otherwise adhere in clumps, the latter resulting in the smothering and death of the inner eggs. It may be that eggs freed by fish spawning in turbid waters rapidly gather a coating which makes them less able to adhere to one another. Eggs falling to the bottom singly might be expected to have a better chance of hatching than those in aggregations.

CONCLUSIONS

Of the factors, other than intensity of fishing, relating to the abundance of certain fishes in western Lake Erie, turbidity of the water is important. A highly significant degree of correlation ($r = +0.79$) has existed for the past 10 years between the mean April-May turbidities as measured at Cleveland and the total Ohio sauger catch 3 years later. There is considerable evidence that the lake turbidities during these months bear a significant relationship ($r = +0.60$) to the mean precipitation in the same months at several points along the southwestern shore of the lake. It is suggested that higher turbidities may act to prevent stickiness in sauger eggs, may give young fry protection from predators, and may facilitate the young saugers' feeding by concentrating plankton organisms near the surface.

LITERATURE CITED

(1) **Davenport, C. B.,** and **M. P. Ekas.** 1936. Statistical methods in biology, medicine and psychology. John Wiley & Sons.
(2) **Deason, H. J.** 1933. Preliminary report on the growth rate, dominance, and maturity of the pike-perches (Stizostedion) of Lake Erie. Trans. Am. Fish. Soc., Vol. 63, pp. 348–360.
(3) **Simpson, G. L.,** and **A. Roe.** 1939. Quantitative zoology. McGraw-Hill.
(4) **Snedecor, G. W.** 1938. Statistical methods. Collegiate Press.
(5) **U. S. Department of Agriculture.** Weather Bureau. (Annual meteorological summaries for Toledo, Sandusky and Cleveland.)

SUPPLEMENTARY NOTE ON THE EFFECT OF THE 1938 HURRICANE

MARY D. ROGICK,
College of New Rochelle,
New Rochelle, New York

The effect of the Sept. 21, 1938, New England hurricane on the ecology of the Fresh Water Pond at Woods Hole, Mass., with specific reference to the Bryozoa was briefly discussed in a previous paper (Rogick, 1940b). Collections had been made in the littoral zone of the specified pond before the hurricane (during the summer of 1938) when the pond water was fresh and the summer after the hurricane when the pond water was brackish. It is still brackish. The present supplementary note deals with the collection made in the same pond during the summer of 1940, more specifically with the collection made on August 1, 1940.

The writer is most deeply indebted to the Woods Hole Oceanographic Institute through whose courtesy and very kind co-operation an analysis of the pond water was obtained. The results of this analysis in parts per thousand were as follows: K—.04; Cl—1.96; Salinity—3.57. Roughly speaking this would be the equivalent of 1 part of harbor water (salt) to about 10 parts of pond water (fresh).

The pond bottom is sandy, with some rocks. As regards the present plant life of the pond no submerged pond weeds were observed. There were some diatoms, filamentous and other algae on the rocks. The top surface of many of the rocks was clean and free from growths of any kind. As regards the present fauna it was found to be not very abundant and not so very different from that of the preceding year. No sponges, coelenterates, platyhelminths, mollusks nor echinoderms were encountered. Among the protozoa were the following: *Euplotes*, *Cinetochilum*, *Zoothamnium*, *Coleps*, *Actinophrys sol*, *Amoeba proteus*, *Amoeba radiosa* and *Euglena viridis*. There were some small free-living nematodes, rotifers and gastrotrichs. There were also a few bloodworms and insect larvae, some in parchment cases, others in sandy cases, copepods, an amphipod *Gammarus fasciatus* and a barnacle *Balanus eburneus*. Of all the species present *Gammarus fasciatus* seemed the most abundant. In fact, it was far more common this year than last.

Most rocks fairly teemed with *Gammarus*. The barnacles were few in number and isolated. All those found were alive and quite large. To some of them were adhering a few algae-surrounded *Fredericella sultana* statoblasts. These statoblasts were split at least partially. A small wad of material or debris was between their valves as if an attempt to germinate had been made but had not advanced very far. At first thought one might suppose that these had been all that remained of *Fredericella* colonies which had settled and grown on the barnacles. However this would be an erroneous conclusion because of several factors. They could not have been formed on the barnacles by living colonies because they occurred in singles, without any definite adherence or deposition pattern, and because they were surrounded and fairly well encased in a thin covering of algal material and some debris. It is quite possible that these statoblasts were formed in 1938, in time washed against the barnacles and were finally attached to them. We must assume that these statoblasts were formed in 1938 (before the hurricane) when living *Fredericella* colonies were very abundant because in 1939 and 1940 no living colonies of fresh-water Bryozoa could be found in the pond, only dead colonies.

TABLE I

MEASUREMENTS OF 13 SESSILE STATOBLASTS OF *Plumatella* sp.

	Maximum in mm.	Average in mm.	Minimum in mm.
Total Length	0.57	0.524	0.48
Total width	.45	.403	.35
Capsule length*	.51	.452	.40
Capsule width*	.35	.325	.30
Vestigial float length	.06	.043	.02
Vestigial float width	.06	.047	.03
Cement ring diameter	.04	.025	.01

* The capsule measurements are inclusive of the cement ring.

The fresh-water forms of 1938 had been replaced by the brackish water form *Membranipora lacroixii* in the 1939 collection (i. e., after the hurricane) while in the 1940 collection neither type was found in the living state. It was a little difficult to understand why *M. lacroixii* was not present in this year's collection but perhaps it may have been due to the low salinity of the pond or to lack of food. Not even dead colonies of *Fredericella*, *Plumatella* nor *Membranipora* were encountered in the 1940 collection. Only sessile or fixed statoblasts of the fresh-water forms (*Fredericella* and *Plumatella*) could be found and these were all dead—remains of the 1938 crop. Most were empty-looking and a number had never germinated. Insect larvae had appropriated some of the statoblast valves for their cases, particularly for those cases which were made up largely of sand grains.

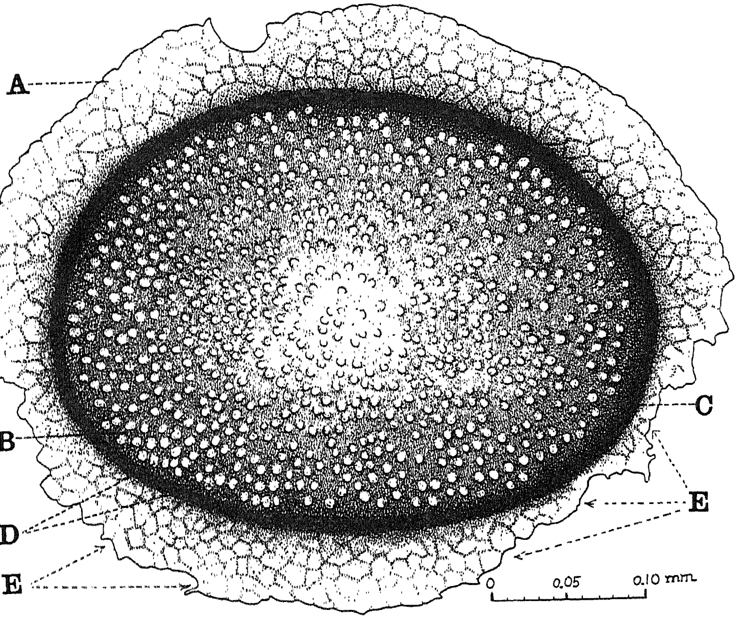


FIG. 1. A view of the upper unattached valve of a sessile *Plumatella* sp. statoblast. This specimen was collected in the Fresh Water Pond at Woods Hole, Mass., on Aug. 1, 1940. It is a very worn specimen as can be judged from the ragged appearance of the vestigial annulus or float or chitinous lamella as it is sometimes known. The annulus slants up a little from the edge of the capsule. Drawn with the aid of a camera lucida, a 5X ocular and a 45X objective. Key to the labels: *A*—vestigial annulus; *B*—capsule; *C*—cement ring; *D*—mammillations; *E*—damaged or worn area.

No free statoblasts of *Plumatella* sp. were found and that was to be expected because they rise to the surface when released, hence are more apt to be lost or missed in collecting. Moreover, they are very tiny, smaller than the sessile statoblasts. A number of sessile *Plumatella* sp. statoblasts were found. Many of these were very worn but still adhering to the rocks, frequently in rows as they were when the colonies were alive in 1938. However, the zooecial tubes had all been worn away and lighter streaks and traceries remained on the rocks where the zooecial tubes had been in previous years. The zooecial tube ectocyst is not so resistant to disintegration as are the heavily chitinized statoblasts which may remain in water for several years without their valves disintegrating.

The identification of these *Plumatella* statoblasts further than the genus from sessile statoblasts alone is extremely difficult in the present case for several reasons: 1, the present lack of floating statoblasts and colonies; 2, the incompleteness of measurements for the various *Plumatella* species described in literature; 3, the considerable variation of both floating and sessile statoblasts of the various fresh-water Bryozoa; and 4, the confused synonymy of the *Plumatella* group. Reference to the measurements given by different authors for the several species and varieties of *Plumatella* did not solve the problem since none of the average measurements agreed completely with those of the Woods Hole *Plumatella* sp. statoblasts. The latter are larger than those of *P. repens typica* or *emarginata* of Study IX, pp. 200, 202, and are smaller than those from the *P. fungosa* var. *coralloides* of Harmer (1913, pp. 451–452). Because of this difficulty of identification it was deemed advisable to picture the statoblasts in Fig. 1 and to give their measurements in Table I.

In conclusion, one might say that there was some change in the fauna of this pond from last year to this. The Bryozoa, in which the writer is especially interested, seem to be in a period of transition. The fresh-water members had been killed off as a result of the accompanying effects of the hurricane late in 1938, the marine or brackish water forms thrived during the summer of 1939 and neither was alive in the summer of 1940. Collections in future years in the same locality should prove interesting.

BIBLIOGRAPHY

Arnold, A. F. 1901. The Sea-Beach at Ebb-Tide. The Century Co.

Harmer, S. F. 1913. The Polyzoa of Waterworks. Proc. Zool. Soc. London, pp. 426–457.

Pratt, H. S. 1935. Manual of the Common Invertebrate Animals. P. Blakiston's Sons & Co., Philadelphia.

Richards, H. G. 1938. Animals of the Seashore. Bruce Humphries Inc., Boston.

Rogick, M. D. 1940a. Studies on Fresh-Water Bryozoa, IX. Trans. Amer. Micr. Soc. LIX: 187–204.

1940b. An Ecological Effect of the New England Hurricane. Ohio Jour. Sci. XL: 163–167.

Ward, H. B., and **Whipple, L. C.** 1918. Fresh-Water Biology. John Wiley & Sons, New York.

PROTOZOAN PARASITES OF THE ORTHOPTERA, WITH SPECIAL REFERENCE TO THOSE OF OHIO

III.[1] Protozoan Parasites in Relation to the Host and to Host Ecology

FRANK MERRICK SEMANS
The Ohio State University
and
Youngstown College

From July, 1932, to October, 1933, a total of 1287 orthopteran individuals were examined, representing 6 families and 99 species. Of these, 34 species and 244 individuals were found to be infected with protozoan parasites, and 33 species and 192 individuals with gregarines. Of 706 males, 131 or 19% were infected with protozoan parasites, and 96, or 14% with gregarines. Of these males, 116 were in nymphal stages and showed 26% infection with protozoan parasites and 8% infection with gregarines. The 590 adult males showed 17% infection with protozoan parasites, 15% with gregarines. Of 581 females, 113 or 19% were infected with protozoan parasites and 96, or 17% with gregarines. Of these females, 123 were nymphs, with 11% infection with protozoan parasites and 11% with gregarines. The 458 adult females showed 22% infection with protozoan parasites and 18% with gregarines.

All nymphs examined (239) showed 18% infection with protozoan parasites, 9% with gregarines. Total adults examined (1048) showed 19% infection with protozoan parasites, 16% with gregarines.

The discrepancies between the numbers of nymph and adult Orthoptera examined were considerable; however, the percentages of gregarine infection indicate that the adults were infected almost twice as often as nymphs. This does not apply to flagellate infection, where the infection of nymphs was close to that of adults.

Female Orthoptera presented a 3% higher degree of gregarine infection than the male. This is not a significant difference, the percentages of infection by all protozoan parasites being practically the same in the two sexes. In a study of the parasites of *Blatta orientalis* Linnaeus, R. Kudo (1926) found a far greater infection by *Lophomonas blattarum* Stein and *L. striata* Bütschli in females than in males. In this study, conversely, the flagellate infection of male Blattidae ran considerably higher than that of females.

---

[1] Part I: Ohio Journal of Science, November, 1936. Part II: Ohio Journal of Science, May, 1939.

The Orthoptera examined are given by family and subfamily. They are classified according to Thomas (1933). References: Mead, 1904; Kirby, 1904, 1906, 1910; Kostir, 1914; Blatchley, 1920.

BLATTIDAE

Five species of Blattidae were examined. *Ischnoptera deropeltiformis* (Brunner) was without parasites; *Parcoblatta virginica* (Brunner), a new host, harbored *Leptomonas* sp. and *Gregarina ohioensis* n. sp. in large numbers; *P. uhleriana* (Saussure), also a new host, harbored *G. parcoblattae* n. sp.; *P. lata* (Brunner), new host, harbored *Leptomonas* sp.; *P. pensylvanica* (DeGeer) harbored *Leptomonas* sp., *Gregarina thomasi* n. sp., *G. parcoblattae* n. sp., and *Nyctotherus ovalis* Leidy, variety.

Of 70 specimens of Blattidae examined, 60, or 86%, were infected with *Leptomonas* sp. in contrast to 15 individuals, or 21%, infected with gregarines. Thirty-eight out of 39 males (97%) were parasitized—all of the 21 nymphs, and 17 of the 18 (94%) adults. Of 31 females, 22 (71%) were infected, all of which were adults. Total nymph infection was 21 out of 23 examined (91%); total adult infection, 39 out of 47 examined (83%).

The flagellate infection of the Blattidae considerably exceeded the gregarine, which is conceivably the result of a difference in the concentration of digestive enzymes in the respective seats of infection, namely, the hind-intestine and the mid-intestine. H. S. Swingle (1925) shows that enzymes are not secreted by the hind-intestine of *Blatta orientalis* Linnaeus but may be found in that section of the alimentary canal near the mid-intestine, having been secreted in the latter. The gregarines are limited to the mid-intestine in their early development, inasmuch as that section of the alimentary canal is the only one where they have access to the epithelial layer, that of the other sections being protected by a chitinous layer; and the adult gregarines tend to remain in the mid-intestine.

Nyctotherus ovalis Leidy, variety ?, was taken from only one specimen (*Parcoblatta pensylvanica* (DeGeer), male nymph), which was surprising, considering the comparatively large number of Blattidae examined. However, this is the only case in which a ciliate has been reported for identified Blattidae other than the domestic cockroaches.

PHASMIDAE

Only one species of Phasmidae was examined—25 specimens of *Diapheromera femorata* (Say), and none of these had protozoan parasites.

This is the only orthopteran family for which no parasites have been reported and for which none were observed in this study.

ACRIDIDAE

Of the Acrididae, 39 species, representing four subfamilies, were examined. Those of the subfamily Acrydiinae are as follows: *Nemotettix cristatus compressus* Morse, unparasitized; *Acrydium ornatum* (Say), unparasitized; *A. arenosum angustum* (Hancock), a new host, harboring *Gregarina acrydiinarum* n. sp.; *Paratettix cucullatus cucullatus* (Burmeister), a new host, harboring *G. acrydiinarum* n. sp.; and *Tettigidea lateralis* (Say), unparasitized.

The species of the subfamily Acridinae are as follows: *Syrbula admirabilis* (Uhler), unparasitized; *Orphulella speciosa* (Scudder), unparasitized; *Dichromorpha viridis* (Scudder), a new host, harboring *Actinocephalus elongatus* n. sp.; *Chloealtis conspersa* Harris, unparasitized; *Chorthippus curtipennis curtipennis* (Harris), a new host, harboring *Gregarina rigida rigida* (Hall), and *G. indianensis* n. sp.

Species of the subfamily Oedipodinae examined are as follows: *Arphia sulphurea* (Fabricius), a new host, harboring *Gregarina rigida columna* n. subsp., *G. r. rigida* (Hall), and *Actinocephalus elongatus* n. sp.; *A. xanthoptera*, unparasitized; *Chortophaga viridifasciata* (DeGeer), a new host, harboring *Gregarina rigida columna* n. subsp. and *Actinocephalus elongatus* n. sp.; *Encoptolophus sordidus* (Burmeister), harboring a new parasite, *Gregarina rigida columna* n. subsp.; *Hippiscus rugosus* (Scudder), unparasitized; *Pardalophora apiculata* (Harris), a new host, harboring *G. rigida columna* n. subsp. and *Actinocephalus* sp.; *P. phoenicoptera* (Burmeister), unparasitized; *Dissosteira carolina* (Linnaeus), harboring a new parasite, *Gregarina rigida columna* n. subsp., in addition to *G. r. rigida* (Hall) and *G. locustae* Lankester; *Spharagemon bolli* Scudder, a new host, harboring *G. rigida columna* n. subsp. and *G. r. rigida* (Hall); *S. planum* Morse, unparasitized; *S. collare collare* (Scudder), a new host, harboring *G. rigida columna* n. subsp.; and *Trachyrachis kiowa thomasi* (Caudell), unparasitized.

Species of the subfamily Cyrtacanthacrinae examined are as follows: *Schistocerca americana americana* (Drury), harboring a new parasite, *Actinocephalus elongatus* n. sp. (?); *S. alutacea* (Harris), unparasitized; *Melanoplus gracilis* (Brunner), unparasitized; *M. facetus* Hubbell, unparasitized; *M. hinei* (Thomas), unparasitized; *M. obovatipennis* (Blatchley), a new host, harboring *Gregarina rigida columna* n. subsp. and *G. r. rigida* (Hall); *M. scudderi scudderi* (Uhler), a new host, harboring *G. rigida columna* n. subsp.; *M. walshii* Scudder, unparasitized; *M. differentialis* (Thomas), harboring *G. rigida columna* n. subsp., *G. r. rigida* (Hall), and *G. indianensis* n. sp.; *M. bivittatus* (Say), harboring *G. rigida columna* n. subsp., *G. r. rigida* (Hall), and *G. indianensis* n. sp.; *M. confusus* Scudder, unparasitized; *M. femur-rubrum femur-rubrum* (DeGeer), harboring *G. r. rigida* (Hall), *G. nigra* Watson, and *G. locustae* Lankester; *M. fasciatus* (F. Walker), unparasitized; *M. mexicanus mexicanus* (Saussure), harboring *G. rigida columna* n. subsp., *G. r. rigida* (Hall), *G. indianensis* n. sp., and *Actinocephalus elongatus* n. sp. (?); *M. keeleri luridus* (Dodge), harboring *Gregarina rigida columna* n. subsp.

and *G. r. rigida* (Hall); *Paroxya hooseri* Blatchley, unparasitized; and *P. atlantica atlantica* Scudder, unparasitized.

A total of 499 specimens of Acrididae were examined, and 87 of these (17%) were infected, the infected specimens representing 19 of the 39 species.

TETTIGONIIDAE

In this study, no protozoan parasites were taken from the Tettigoniidae, although 285 specimens, representing 29 species, were examined. Only one protozoan parasite has been reported from the Tettigoniidae, namely, *Gregarina chagasi* Pinto (from *Neoconocephalus fratellus* (Griffini)). An adequate description of this gregarine is not available, and there is no illustration of it, hence its relation to the other gregarines cannot be determined.

The Tettigoniidae examined were as follows: *Scudderia curvicauda curvicauda* (DeGeer); *S. texensis* (Saussure and Pictet); *S. furcata furcata* Brunner; *Amblycorypha oblongifolia* (DeGeer); *A. uhleri* Stal; *A. rotundifolia rotundifolia* (Scudder); *Microcentrum rhombifolium* (Saussure); *M. retinerve* (Burmeister); *Pterophylla camellifolia* (Fabricius); *Neoconocephalus exiliscanorus* (Davis); *N. nebrascensis* (Bruner); *N. lyristes* (Rehn and Hebard); *N. robustus crepitans* (Scudder); *N. ensiger* (Harris); *N. palustris* (Blatchley); *N. retusus* (Scudder); *Orchelimum vulgare* Harris; *O. sylvaticum* McNeill; *O. nigripes* Scudder; *O. concinnum* Scudder; *O. campestre* Blatchley; *Conocephalus fasciatus fasciatus* (DeGeer); *C. brevipennis* (Scudder); *C. nemoralis* (Scudder); *C. strictus* (Scudder); *C. nigropleurum* (Bruner); *Atlanticus testaceus* (Scudder); *A. davisi* (Rehn and Hebard); and *A. americanus* (Saussure).

GRYLLACRIDAE

Eleven species of Gryllacridae were examined. These were as follows: *Tachycines asinamorus* (Adelung), a new host, harboring *Pileocephalus tachycines* n. sp.; *Hadenoecus puteanus* Scudder, a new host, harboring *Gregarina hadenoeci* n. sp.; *Ceuthophilus pallidipes* E. M. Walker, unparasitized; *C. latens* Scudder, unparasitized; *C. gracilipes* (Haldeman), a new host, harboring *G. proteocephala* n. sp. and *G. ceuthophili* n. sp.; *C. meridionalis* Scudder, unparasitized; *C. brevipes* Scudder, harboring a new parasite, *G. ceuthophili* n. sp.; *C. divergens* Scudder, a new host, harboring *G.* sp. and *G. ceuthophili* n. sp.; *C. uhleri* Scudder, a new host, harboring *G. prima* n. sp.; *C. nigricans nigricans* Scudder, unparasitized; and *C. thomasi* Hubbell, unparasitized.

Of a total of 145 specimens of Gryllacridae, 38, or 26%, of the individuals, and 6 of the 11 species, were infected.

GRYLLIDAE

Of the Gryllidae, 14 species, representing four subfamilies were examined. Seven species of Gryllinae were as follows: *Gryllus assimilis* Fabricius, for which new parasites were named, harboring *Leidyana gryllorum* (Cuenot), *L. erratica* (Crawley), *Gregarina kingi* Crawley, *G. galliveri* Watson, and *G. oviceps* Diesing; *Gryllus domesticus* Linnaeus,

unparasitized; *Miogryllus verticalis* (Serville), unparasitized; *Nemobius fasciatus fasciatus* (DeGeer), a new host, harboring *Leidyana gryllorum* (Cuenot) and *L. erratica* (Crawley); *N. fasciatus tinnulus* Fulton, unparasitized; *N. fasciatus socius* Scudder, a new host, harboring *L. erratica* (Crawley); *N. maculatus* Blatchley, unparasitized.

Three species of the subfamily Oecanthinae were as follows: *Oecanthus nigricornus quadripunctatus* Beutenmüller, unparasitized; *O. nigricornus nigricornus* F. Walker, unparasitized; and *O. latipennis* Riley, unparasitized. It is interesting to note that no protozoan parasites have been reported from the Oecanthinae, although some of the same species of gregarines have been taken from subfamilies of the Gryllidae which are placed taxonomically on either side of the Oecanthinae by the orthopterists. This suggests, perhaps, a closer relationship between such isolated groups than has heretofore been suspected. The granular contents of the oecanthin gut are totally unlike the gut contents of the other Gryllidae examined by the author—a factor which may be correlated with the absence of parasites.

Two species of Trigonidiinae examined were *Anaxipha exigua* (Say), a new host, harboring *Leidyana erratica* (Crawley); and *Phyllopalpus pulchellus* Uhler, unparasitized.

Two species of Eneopterinae examined were *Hapithus agitator agitator* Uhler, a new host, harboring *Leidyana erratica* (Crawley), and *Gregarina galliveri* Watson; and *Orocharis saltator* Uhler, unparasitized.

Of a total of 263 specimens of Gryllidae examined, 52, or 20%, of the individuals, and 5 of the 14 species were infected.

The Orthoptera examined harbored protozoan parasites from three classes of Protozoa, namely, the Mastigophora (*Leptomonas* sp. in the Blattidae), the Sporozoa (many Gregarinida, in four families of Orthoptera), and the Infusoria (*Nyctotherus ovalis* Leidy, variety ? in one species of Blattidae).

SEAT OF PROTOZOAN PARASITE INFECTION

The predominating seat of gregarine infection is the extreme anterior end of the mid-intestine at the base of the enteric ceca. The infected region is often in a disintegrated condition—a dark, sticky mass—and for this reason it is often difficult if not impossible to determine to what extent the enteric ceca and the anterior end of the mid-intestine are involved. Occasionally only one or two ceca are infected; and sometimes, on the other hand, nearly the entire mid-intestine, or isolated spots towards the middle or posterior end are infected. It is doubtful that the anterior end is more susceptible to infection than any other part, but the sporozoites are probably liberated in that region by the action of enzymes on the spores and immediately penetrate the host tissue.

When the gregarine infection becomes well advanced, the sticky mass supplants the normal host tissue, and the gregarines appear on the celomic side, always adhering to the mass.

Gregarine cysts are found throughout the entire length of the mid- and hind-intestines. They are usually in masses along with sporonts and associations in the mid-intestine; in the hind-intestine they may be found isolated among particles of debris in the gut contents. The largest number of cysts was found in some hosts which had been dead for about twelve hours, and it is likely that the uncontrolled action of the digestive enzymes after the death of the host is responsible for the encystation.

HOST ECOLOGY

Ecological factors were recorded for each of the localities in which Orthoptera were collected, and some suggestive correlations were noted.

In general, where the vegetation was abundant, the insect gut was distended and more likely to be parasitized. The greatest degree of parasitism was that of the acridid grasshoppers taken in the fairly abundant vegetation of the pockets of the arrested Indiana sand dunes, about a mile from the Lake Michigan shore. These acridids were almost 100% parasitized and their alimentary canals were expanded from feeding. Nowhere else were those particular species of Orthoptera found in such large numbers, and since they are scavengers and often cannibalistic, their prevalence was an additional factor contributing to the presence of many parasites. On the other hand, the acridids of the extremely arid prairie of the Kettle Hills (Fairfield County, Ohio) showed very little parasitism and were small gutted.

It is of interest to note that only those Orthoptera which live in burrows and cracks, or under logs and stones, and are carniverous, are especially parasitized. (There is a possibility of a light factor as well as the scavenger habits of the host influencing the prevalence of parasites.) Seasonal duration of the subdivisions of the Orthoptera might be considered a factor also, but the duration of the Acrididae, which are parasitized, is not essentially different from that of the Tettigoniidae, which are not parasitized.

In an attempt to correlate the pH of the anterior end of the orthopteran mid-intestine with protozoan prevalence and soil pH, 37 specimens of 4 families were studied. These were: 12 specimens of Acrididae with intestinal pH averaging 6.0; 4 specimens of Gryllacridae with intestinal pH averaging 5.9; 18 specimens of Tettigoniidae with intestinal pH averaging 5.6; 3 specimens of Gryllidae (*Oecanthus* spp.) with intestinal pH averaging 5.6. The degree of anterior mid-intestine acidity may be a factor in excluding parasites from the Tettigoniidae and certain Gryllidae (*Oecanthus* spp.), as the average pH of these groups was somewhat lower than that of the others examined.

Relating intestinal pH to the soil pH of the localities in which the insects were collected, it was found that 7 specimens were from localities with soil pH of 7.0, and their intestinal pH ranged from 5.9 to 6.6, averaging 6.3. The other 30 specimens came from localities where the soil pH was from 4.8 to 6.4, and their intestinal pH ranged from 5.6 to 5.9, averaging 5.7. Hence, intestinal acidity may possibly be correlated with that of the soil.

Each of the ecological factors constitutes a problem in itself, and many further possibilities for research are indicated.

SUMMARY

Ninety-nine species of Orthoptera were examined, with 34% infection; 1287 individual specimens, with 19% infection.

It is indicated that the protozoan parasites of the Orthoptera are host-specific for families and, to some extent, for subfamilies.

Protozoan parasites were taken from species of all of the major subdivisions of the Orthoptera studied, except the Phasmidae, Tettigoniidae, and Oecanthinae (subfamily of Gryllidae). The distinctive appearance of the gut contents and the gut pH of the latter two were correlated with the absence of parasites in these groups. The number of Phasmidae was too small to justify making a statement concerning the absence of parasites.

Twenty-two (or 24?) new hosts were recognized, and 12 (or 10?) hosts already studied were assigned new parasites. (The exact number is doubtful because of a few inaccurate host determinations made in the past.)

The infection by cephaline Gregarinida of nymph Orthoptera was approximately one-half as frequent as that of adults, but the degree of infection by flagellates (one species) was about the same in nymphs and adults. Female insects were infected by gregarines slightly more often than males; not nearly so often by flagellates. Ciliates (one species) were taken from one host only. No amoebae were observed.

The predominating seat of gregarine infection was the extreme anterior end of the mid-intestine at the base of the enteric ceca. However, other parts of the mid-intestine, including the enteric ceca were sometimes infected. Flagellates and ciliates were taken from the hind-intestine, particularly the colic region.

The average pH of the anterior end of the mid-intestine of Tettigoniidae and *Oecanthus* spp. of the Gryllidae (where there is probably no parasitism) was lower than that of specimens of two other orthopteran subdivisions which are known to be freely parasitized. There was a tendency for the gut pH to correlate with that of the soil of the locality in which the insect lived.

In general, the greatest degree of parasitism was in well-fed Orthoptera which were terrestrial, scavengers, and cannibalistic.

LITERATURE CITED

Blatchley, W. S. 1920. Orthoptera of northeastern America. The Nature Publishing Co., Indianapolis.

Kirby, W. F. 1904, 1906, 1910. A synonymic catalogue of Orthoptera. 3 vols. British Museum, London.

Kostir, W. J. 1914. Additions to the known orthopterous fauna of Ohio. Ohio Nat., 15: 370–374.

Kudo, R. 1926. A cytological study of *Lophomonas striata* Bütschli. Arch. Protistenk., 55: 504–515.

Mead, C. S. 1904. A list of the Orthoptera of Ohio. Ohio Nat., 4: 109–112.

Semans, F. M. 1936 and 1939. (See footnote, p. 1, in this paper.)

Swingle, H. S. 1925. Digestive enzymes of an insect. Ohio Jour. Sci., 25: 209–218.

Thomas, E. S. 1933. Check list for Ohio Orthoptera. Unpub. MS. Ohio Museum, Columbus, Ohio.

Two New Bird Books

The aim of the publishers of these books has been to produce a pair of inexpensive books containing a colored picture and a brief description of the more common birds of eastern United States. Some 215 species are illustrated in the two volumes and for each of these (and about a dozen others) there is a brief description of 2–4 lines, followed by a paragraph or two about the bird. The text is simple, clear, and generally accurate.

The colored plates, 30 in each book, are those of Louis Agassiz Fuertes, borrowed from the New York State Museum. These plates are apparently becoming worn, as the reproduction in these books of a few of them is none too good. The order of the plates and species discussions follows that in "The Birds of New York," hence it does not conform entirely with the order in the latest (1931) A. O. U. Check List.

In the volume on songbirds there is a brief introduction on "Some Hints for Bird Study," which is well written and contains some good suggestions for the beginner. This is followed by the accounts of the species illustrated. In the first (songbird) volume the only references to plates are in the index; in the second the references to illustrations are in each description. No scientific names are mentioned anywhere in either book. The second book shows certain improvements over the first, particularly in the brief discussions of the more important bird groups; only a few groups are so treated in the songbird volume. At the end of each book is an index to the species treated, and a list of other books useful to the bird student.

In selecting species for treatment the author has selected 60 of the 106 Fuertes plates, and has discussed each species on these plates. The result is that a few unusual species (e. g., European goldfinch, evening grosbeak, purple sandpiper, and others) are included, while some fairly common species (e. g., the grebes, rails, some of the shore birds, the goatsuckers, waxwings, shrikes, and others) are omitted.

These books are handsomely gotten up and are printed on a good grade of heavy glazed paper. They are well bound and should stand considerable use. The particular volume on songbirds which this reviewer received lacked pp. 61–68, and had pp. 37–44 repeated in their place; it is a bit annoying to encounter this sort of thing in any book.

The general attractiveness of these books, and their low price, should insure their wide use. They are most siutable for juvenile readers and beginners in bird study; as reference books on birds they are of value largely because of the plates they contain, and in this respect they are incomplete.—*D. J. Borror.*

American Songbirds, by Maitland A. Edey. 72 pp. New York, Random House. 1940. $1.00.

American Water Birds, also Hawks, Owls, and Game Birds, by Maitland A. Edey. 72 pp. New York, Random House. 1941. $1.00.

INDEX TO VOLUME XLI

Abernathy, E. R., 123.
Additions to vascular plants, 328.
Aerial Traverse, 212.
Agelenopsis, 51.
Albright, J. G., 70.
Alcohols, 431.
Alexander, W. H., 288.
Alexopoulos, C. J., 425.
Anemometer Cups, 70.
Antibiosis, 425.
Aquila Chrysaetos, 46.
Arteries, 99.
Auditory Mechanisms, 117.
Aves, 99.

Bacteria, 425.
Bangham, R. V., 23, 441.
Bellevue, 366.
Black Widow Spider, 380.
Blood, 347.
Braun, E. L., 235.
Brill, H. C., 431.
Buckeye Lake, 441.
Buprestidae, 381.
Buteo borealis borealis, 46.
Butomus umbellatus, 79.

Caldwell, J. S., 418.
Cambarus sloani, 93.
Cancer, 135, 139.
Cerambycidae, 381.
Cicadellidae, 86.
Coccyzus americanus, 99.
Coleoptera, 381.
Columba livia, 46.
Concon, E. V., 131.
Conrey, G. W., 201.
Core, 79.
Corum, C. J., 389.
Crile, G., 347.
Crotophaga ani, 99.
Culler, E. A., 117.

Dalton, 105.
Daugherty, R. R., 366.
Deafness, 123.
Deciduous Forests, 235.
De Long, D. M., 86.
Deuterium, 357.
Doan, K. H., 449.
Drosophila, 190.

Eagle, 46.
Ecology, 190.
Encephalization, 173.
Ethers, 431.
Evans, W. L., 105.

Fish, 441.
Fulton, J. F., 173.
Fungi, 425.

Gasser, H. S., 145.
Geography, 212.
Gerard, R. W., 160.
Glasser, O., 347.
Glenny, F. H., 46, 99.
Goldfish, 431.
Gourley, J. H., 242.
Growth, 389.

Hall, W. H., 357.
Hawk, 46.
Heart, 347.
Heavy Water, 357.
History, 288.
Homoptera, 86, 418.
Horticultural Research, 242.
Human Inheritance, 89.
Hurricane, 453.
Hydrogen-ion Concentration, 389.
Hymenoptera, 29.

Johnston, H. L., 357.
Jones, C. H., 328.

Klein, G. E., 70.
Knullana, 86.
Knull, J. N., 381.
Kraatz, W. C., 1.

Lake Erie, 449.
Lampe, I., 135.
Latrodectus mactans, 380.
Ligamentum botalli, 46.

Mack, E., 183.
Mitchell, R. T., 29.
Motor Functions, 173.

Nerve Fibers, 145.
Nervous System, 173.
Neurones, 160.
Neutrons, 131, 135.

Ohio Academy of Science, 288.
Orthoptera, 457.

Parasites, 441.
Park, O., 39.
Pentastomida, 23.
Pigeon, 46.
Plankton, 1.
Plastoceridae, 381.
Post-glacial Vegetation, 225.

Prehistoric Factors, 207.
Pressnell, A. K., 431.
Protein Structure, 183.
Protozoan Parasites, 441.
Psyllidae, 418.

Quiring, D. P., 347.

Radioactivity, 131, 135.
Rhoades, R., 93.
Rich, J. L., 212.
Rogick, M. D., 453.
Rythmicity, 39.

Saga of Paddy's Run, 313.
Sauger, 449.
Schaffner, J. H., Memorial, 253.
Sears, Paul B., 225.
Sebekia oxycephala, 23.
Semans, F. M., 380, 457.
Seyler, P. J., 51.
Snyder, L. H., 89.
Spencer, W., 190.
Spiders, 51.
Soils, 201.

Transeau, E. N., 207.
Turbidity, 449.

Vascular Plants, 328.
Vegetation, 207.
Vernard, C. E., 23.
Vespidae, 29.
Vespula manulifrons, 29.

Waller, A. E., 253.
Water, Heavy, 357.
Williams, S. R., 313.
Wood, F. C., 139.

X-radiation, 135.

I.A.R.I. 75

INDIAN AGRICULTURAL RESEARCH
INSTITUTE LIBRARY, NEW DELHI.

Date of Issue	Date of Issue	Date of Issue
16.1.59		
16.10.59		
26.8.60		
14.4.65		

GIPNLK—H-40 I.A.R.I.—29-4- 5—15,000